LAND USE CHANGE SURROUNDING THE DENVER INTERNATIONAL AIRPORT BETWEEN 1990 AND 2000

By

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The Plan for a New Airport

In 1989, the voters of Denver, Colorado approved plans for the construction of a new international airport. This airport was part of a bigger plan designed to boost the stagnating economy of Denver. Other parts of the plan included a convention center, a beltway linking the interstates surrounding the city, a riverfront park, and a baseball stadium if the city succeeded in acquiring a major league franchise. The convention center was built under budget in 1990, which gave the citizens confidence to back the multi-billion dollar airport project (Faircloth, 1997). Another part of the plan was achieved in 1993 when the Colorado Rockies baseball team was awarded to Denver. These projects were all part of the plan to boost the economy of Denver, but it was believed that the construction of a new airport was the single most important factor.

The planned airport was to replace the older Stapleton International Airport, which was considered a bottleneck in the airline network. Subsequently there was both national and local interest in a new airport. These factors combined with the expected economic impact of a new airport, helped fuel the development of the airport. Not everyone approved of the construction of a new airport and the project was opposed by both the airline industry and local citizens

who believed that an expansion of Stapleton was more appropriate. This led to several years of intense debate before the construction of the airport began on September 28, 1989.

Problem Statement

Airports today are an integral part of the urban environment, and it is therefore important to look at how they affect this environment. The relationship between transportation and economic development is close, and since air transportation is the single most important piece of infrastructure in today's society, their relationship should be carefully examined (Dempsey *et al.*, 1997). The question, then, is what economic development can a city expect if it increases its aviation capacity?

There have been numerous studies dealing with the impact of airports. These studies focus either on the negative or the positive impacts associated with different airports. A typical negative impact study would examine the impact of noise on property values, such as Nelson (1980). An example of a classical positive study measures the direct, indirect, and induced increases in output, income, or employment, such as in Montalvo (1998). It is evident that airports do have an impact on the surrounding area, but the question is to what degree?

Airports are very expensive to build and it is therefore important to estimate the impacts before such a project is started, especially to gain local support. This was also the case in Denver, where studies found that there would

be a positive economic effect if the construction of a new airport were undertaken (Dempsey *et al.*, 1997). This was very important to the Denver community because economic growth, especially in the property market, had stagnated after "the collapse of the energy boom in 1983" (Weiss, 1989, p.14). In relation, it was believed that the construction of a new airport would boost the economy more than an expansion of Stapleton and that this would come at a smaller cost. Expected economic gains would include employees at the airport moving to the area in order to decrease their travel cost, or companies relocating to the area to use the services provided by the airport to their benefit.

Studies have shown that within the areas greatly affected by noise, there will be a decrease in residential property values (Nelson, 1980), whereas the price on commercial property will increase due to an increased demand (Pitt and Jones, 2000). This is expected since no one wants to live in the vicinity of an airport, whereas companies want to be close to the airport and the benefits it provides. The consequence of this is often the implementation of different zoning boundaries in order to regulate desired and undesired land use. This was also the case in Denver, where the city of Aurora just south of the new airport had annexed larger tracts of land during the 1980s to serve the city during further expansion. Aurora is one of the places expected to gain the most from the new airport since it is located where the main road from the airport exits. The site originally selected for the new airport was moved several miles to the north as a result of pressure from the city of Aurora to protect newly annexed land planned for residential development (Weiss, 1989). The final site was a 53 square mile

area of considerably rural land 23 miles northeast of downtown Denver in the neighboring Adams County.

What is interesting about Denver International Airport is that it is the first major airport that has been constructed at a new site in the United States since the airport in Dallas/ Fort Worth opened in 1973. The goal of this project is therefore to look at the land use change over time in order to identify patterns that might help explain what has happened and why. Projections for the expected impact are often very optimistic and it would be of great interest to see if there has actually been a distinct change in the land use and what might explain this. Further more, the Organization for Economic Co-operation and development (OECD) stated in 1975 that when an airport is constructed outside the city, as was the case in Denver, the development of that city will be pulled in that direction by attracting compatible land use.

Scope

As mentioned earlier, Denver International Airport is a new airport and the only one to be built at a new site in the United States since 1973. This study is therefore of great interest because it could identify impacts that might be expected if another city decides to build a new airport. The goal is to show the change in land use from when the decision to build the airport was made in 1989 until the present time. The identification of the land use change is essential to this and will be done at two different levels. First, there will be a large-scale

comparison of the land use trends surrounding the entire airport. Secondly, a small-scale comparison of the trends in the northern part of Aurora will be examined.

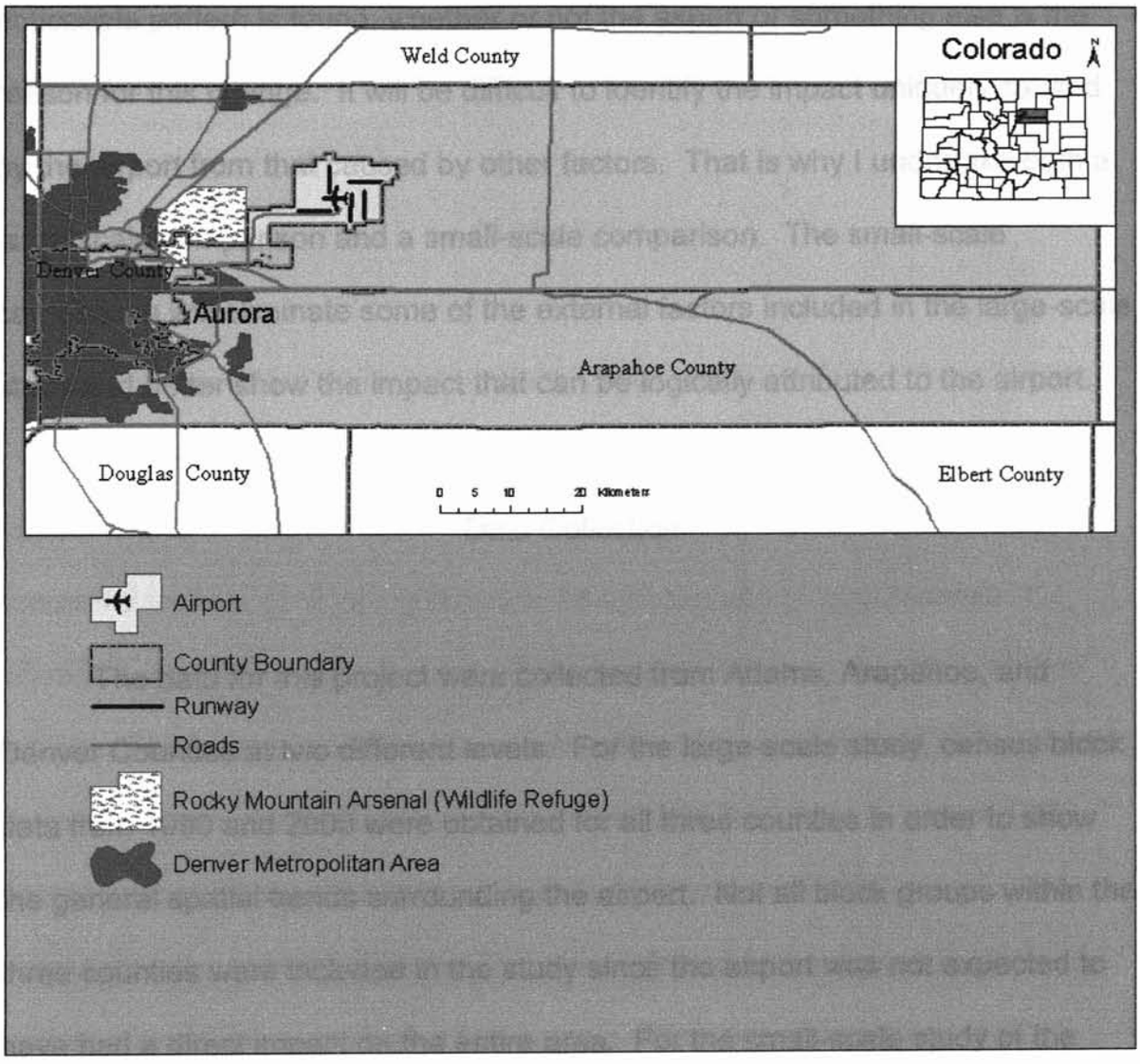
Hypothesis & Research Problems

This investigation will be built up around the following hypothesis: the land use patterns around Denver International Airport have changed significantly between the time the airport was planned in 1989 and the present. In order to answer this hypothesis, the study will be divided into two parts, a large-scale comparison of census block data and a small-scale comparison of the trends in Aurora. Figure 1.1 shows the Denver International Airport and surrounding area.

The following research questions will be used to evaluate the hypothesis:

1. Has there been a detectable change in the land use?
2. What type of development has taken place?
3. Has there been a noticeable increase in the activities that can be logically attributed to the presence of the airport?
4. Has the airport had a positive effect on the areas close to the main entrance and a negative effect in areas further away, especially those affected by the noise produced by the airport?

Figure 1.1 – Denver International Airport and Surrounding Area



Another issue considered in the evaluation of the hypothesis is, if a noticeable pattern is found, whether or not the airport or something else is the reason for this change. It will be difficult to identify the impact uniquely caused by the airport from that caused by other factors. That is why I undertake both a large-scale comparison and a small-scale comparison. The small-scale comparison will eliminate some of the external factors included in the large-scale study and better show the impact that can be logically attributed to the airport.

Data Collection

The data for this project were collected from Adams, Arapahoe, and Denver Counties at two different levels. For the large-scale study, census block data from 1990 and 2000 were obtained for all three counties in order to show the general spatial trends surrounding the airport. Not all block groups within the three counties were included in the study since the airport was not expected to have had a direct impact on the entire area. For the small-scale study of the northern part of Aurora, parcel data were obtained from the Adams County Assessors Office. The zoning boundary for the entire City of Aurora was collected from the City of Aurora. The zoning and parcel data were categorized in order to better identify the spatial characteristic of the things that have happened in Aurora and surrounding area since the airport was planned in 1989.

The airport noise and height boundary was also used in this study to better explain and identify unique patterns. These two boundaries might help

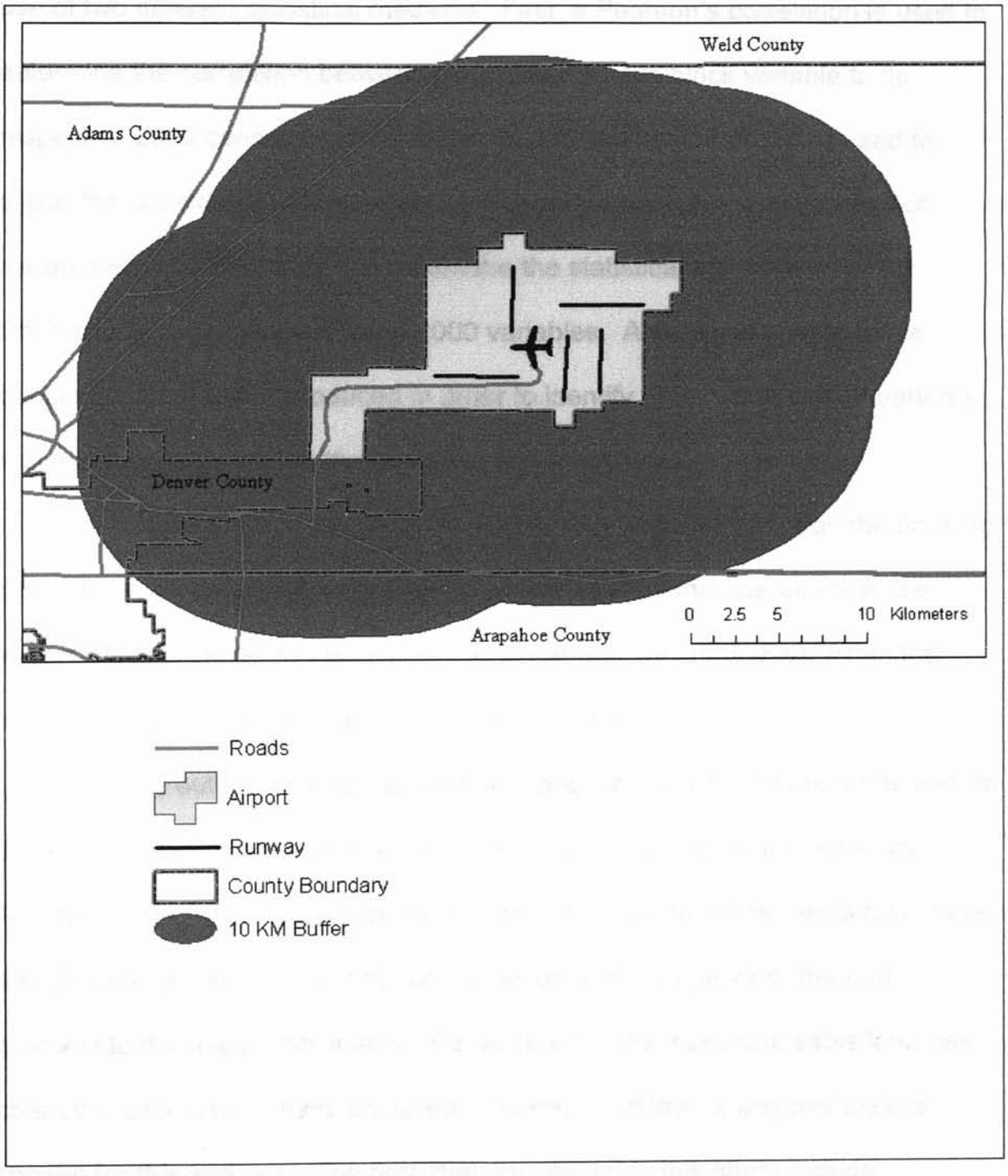
explain different patterns in the areas affected by noise and those not affected. A more thorough discussion of the data and subsequent manipulations is given in Chapter III.

Methodology

The collected data for this project is manipulated in four different ways. First, ArcGIS is used to select the area of interest surrounding the airport and visually display the land use patterns. Second, the population census data is compared for its statistical significance through the use of a two-sample difference of means test and a correlation analysis between the different time periods. Third, the airport height and noise-boundary is compared to the housing characteristics in the area. Fourth, the parcel data for Aurora is grouped into descriptive categories that will help explain what occurred in the area surrounding the airport entrance. The parcel data is further tested for its statistical significance through a two-sample difference of proportion test.

It is expected that the economic impact of the airport is most noticeable in the vicinity of the airport. Therefore, the first step in the analysis of the census block data for Adams, Arapahoe, and Denver Counties is to eliminate the areas not directly affected by the presence of the airport. Since the impact is expected to decrease as the distance to the airport increases, a buffer is applied to the census block data using ArcGIS to eliminate undesired blocks. Figure 1.2 shows the ten kilometers buffer zone that is used in this study.

Figure 1.2 – 10-Kilometer Buffer Zone



The statistical significance of the population change is tested through the use of two different statistical methods. First, a Pearson's correlation is used to determine the correlation between each 1990 census block variable to its respective 2000 census block variable. In addition, a scatter-plot is used to check the covariance of the variables. Second, a two-sample difference of means test is further utilized to determine the statistical significance of the difference between the 1990 and 2000 variables. A series of figures of the population change are produced in order to identify any unique spatial patterns that might be attributed to the presence of the airport.

It is expected that the airport would have a negative effect on the housing characteristics, especially within the areas affected by the operations at the airport. This is tested by comparing the percent of vacant houses within the buffer zone to the airport height and noise boundary.

To find out more specifically what economic impact the airport has had on the surrounding community, the City of Aurora is selected for a case study. Aurora is one of the places expected to gain the most from the new airport since it is located just southwest of the airport where Peña Boulevard, the main gateway to the airport, originates. Subsequently, the most noticeable land use change is expected to have occurred in Aurora, and that is why this area is chosen for this analysis. The data that are utilized in this study include shapefiles of the parcels and zoning boundaries for the area just south of the airport. ArcGIS is used to categorize the data by its respective land use categories for further interpretation. Subcategories within each of these are

utilized to better characterize what happened within the study area. The significance of the change in the number of parcels is tested through a two-sample difference of proportion test.

In summary, the purpose of this study is to identify distinct geographical patterns in the area surrounding the Denver International Airport. Of specific interest is the identification of where the change has occurred, and why.

Limitations

Some important limitations should be mentioned before any analysis is attempted. The choice of the size of the buffer zone imposed on the data in the analysis of the census blocks could have been created differently, which in turn would have produced a different result. The reason I chose a 10-kilometer buffer is that this buffer encompasses almost the entire airport height-boundary and all of the airport noise-boundary. It should always be kept in mind that another buffer could have been chosen. The same issue is relevant in the analysis of the parcels and zoning boundaries in Aurora because here again an alteration of the size of the study area could generate a different result.

Another issue that should be kept in mind is that the Denver International Airport was not the only factor affecting the economy in that area. Therefore, a change in land use may not necessarily be directly attributed to the airport.

Project Significance

There have been a number of studies of airports and the impact they have had on the surrounding area; this includes economic impact studies and studies of the negative effects. There have only been a few geographical studies of the spatial change associated with the construction of a new airport. To date, the Denver International Airport has not been studied in this manner. Therefore, this study is important for four reasons.

First, airports are very important to the local economy, especially in their ability to attract economic development. Hence, it is important to identify what does happen if a new airport is built, so that other communities can see what might be expected in a similar case.

Second, airports are very expensive to construct and public support is often gained by selling the idea of a new airport on the expected positive impact on the local community. It is therefore important to show if there actually has been a significant positive impact.

Third, by examining the land use patterns surrounding the Denver International Airport, it is possible to identify areas that are more likely to attract a specific type of development in the future. This will also provide insight into the diversity of the land use surrounding the airport.

Finally, this study will provide other scholars with a more thorough understanding of the land use impact associated with a major airport. The study is designed to give a more complete understanding of the geography of airports

in the United States, and it is hoped that it will inspire others to engage in similar studies.

CHAPTER II

LITERATURE REVIEW

This chapter provides a discussion of relevant literature related to the impact an airport has on the area where it is located. Each of the following four sections discusses the major works in each respective area, in order to show how airports have an impact on the local community, whether it is positive or negative.

The Economic Impact of Airports

Anthony G. Hoare (1975) developed one of the first studies of the economic impact of airports. He used a model that compared the actual number of firms per area to the expected number. His hypothesis was that the presence of Heathrow Airport, in England, was an important location factor for firms in their decision on where to locate, and that there would be a concentration of firms within a buffer from the airport. The main focus was on the location of foreign firms because they were thought to be especially sensitive to the presence of a major international airport. The result of the comparison between the expected and actual number of firms did not produce any significant pattern (Hoare, 1975). He then conducted a survey and found that within a 30-mile radius, the proximity to Heathrow was of significant importance to some firms in their location decision

(Hoare, 1975). In relation, the proximity of Heathrow was of greater importance to foreign firms as compared to domestic firms. It is important to note that even though some firms thought of the airport as important in their location decision, most of the firms, even within the buffer, did not find the proximity of the airport to be of significant importance. This is probably due to the fact that there were other factors attracting firms to the area surrounding Heathrow, such as the proximity to London and the attraction of living in that area (Hoare, 1975). The presence of the airport made the decision to locate within the 30-mile radius less difficult, but it was not the only factor in determining the location decision.

At the same time Hoare was working on his study in England, the Organization for Economic Co-operation and Development (OECD) was preparing a report on an alternative approach to the measurement of the economic impact of airports. The report identified two important factors to study, direct and indirect impacts (OECD, 1975). In 1986, the Federal Aviation Administration (FAA) and the US Department of Transportation published a document with a proposed methodology for the study of the economic impact of airports. They also proposed the measurement of the direct and indirect impacts, but additionally included the study of the induced impact (FAA, 1986). Further, when the European Region of Airports Council International launched their proposed methodology for the measurement of the economic impact of airports in 1993, it utilized the same three impact categories; direct, indirect and induced (Montalvo, 1998).

The direct or primary impact is defined as "the consequence of economic activities carried out at the airport by airlines, airport management, fixed base operators and other tenants with a direct involvement in aviation" (Montalvo, 1998, p.188). This is the immediate economic activity that takes place at the airport and is either measured through income, employment, or payroll.

The indirect or secondary impact is the "additional indirect expenditure and employment that arise from the stimulus of the direct effects expenditure" (Pitfield, 1981, p.22). This leads to the multiplier effect of the direct impact. The following example will illustrate the concept of the multiplier effect. A restaurant near the airport has to increase it staff due to the increased demand created by the presence of the airport, so the multiplier is the extra job created by the direct impact. In general, the indirect effect is seen as the employment created by the primary employers spending money.

The induced impact is the multiplier effect that results from the direct and indirect impacts recipients' expenditure in the community (Montalvo, 1998). If we continue with the previous example, a person gets a job at the restaurant due to the increased demand created by the airport will go out into the community to spend part of his/her salary. The establishment of new firms and the relocation decision made by others because they want to be within a certain proximity of the airport are also included in this category. This might include a firm seeking a cost advantage of the location close to the airport. In connection, one thing is important to consider when looking at a new activity, and that is to determine whether the activity would have happened if the airport was not there, or if the

Table 2.1 – Direct, Indirect, and Induced Impact

Direct Impact	Indirect Impact	Induced Impact
Airlines	Travel Agents	Output
Maintenance	Restaurants	Income
Catering	Hotels	Employment
Dutty free shops	Off site ground transportation	Taxes
Restaurants	Business related with the	
Taxis	airport	
Car rental	Crew expenditure	
Government agencies	Shops	
Cleaning	Leisure activities	
Other shops	Fuel value added	

Source: Montalvo, Jose G. (1998). A Methodological Proposal to Analyze the Economic Impat of Airports. *International Journal of Transport Economics*. Vol.25(2), p.188, Figure 1.

presence of the airport in that area is the main reason for this new activity. Table 2.1 shows some of the economic activities that might be included under the three impact categories.

It is often hard to distinguish the impact caused by an airport from that of other activities located in the vicinity of the airport. One method often used is the Keynesian approach, which looks at the three impact categories and determines the multiplier that should be applied when determining the economic effect of an airport (Pitfield, 1979). The multiplier is the number the direct impact should be multiplied by in order to get the entire impact. For example, if the multiplier is found to be two, this indicates that for each job created at the airport, another job is created elsewhere. Overall, the total number of employees at the airport should be multiplied by 2 to get the total increase in employment that can be traced back to the airport. The multipliers, depending on the study, can be used

to measure the change in output, employment, or income due to the presence of an airport (Montalvo, 1998). There are different methods that can be used to find the multipliers, such as econometric modeling or input-output analysis.

The following is a comparison of the econometric modeling and the input-output analysis, and why some think that the econometric modeling better captures the impact caused by an airport. Using the two models will more than likely always return different results, but the difference in the results will especially be evident when studying the impact of an airport. According to Oster *et al.* (1997), the econometric modeling should be preferred over the input-output model since the econometric method does not capture the entire economic impact of a major transport facility such as an airport. By contrast, the input-output analysis does capture the increase in employment, but not the relocation of companies to the area because they prefer to be within the vicinity of the airport. Another problem with the input-output analysis is that it is only a snapshot in time, and in addition it is not possible to estimate when the effect will occur (Oster *et al.*, 1997). This evidence suggests that the use of an econometric model might be preferable in the study of the impact of an airport.

Oster *et al.* (1997) compared the difference in results between the two types of models. This study contrasted the impact of investments in the transportation sector in four major cities in the United States. The study found that if the airport was a major hub, the employment multiplier was between 2.0 and 2.2 using the input-output analysis, and between 3.7 and 4.5 using the econometric model (Oster *et al.* 1997). This shows that the choice of method will

greatly affect the size of the multiplier and the implied economic impact. As already discussed, it is perceived that the multiplier found using the econometric model is the one that should be used since a major hub will alter the location decision of other businesses, including those outside the transportation sector. Other studies have also shown that the choice of method greatly affects the result. In one study, two different procedures where used to derive the impact of Heathrow Airport. One of the studies found an employment impact of 199,000, and the other one of 77,000 (Pitfield, 1979). This again shows that it is possible to generate notably different numbers for the level of impact depending on the choice of method.

Montalvo (1998) presented the results of different economic impact studies. Table 2.2 summarizes the average economic impact of these studies. The table shows that the economic impact can be divided into three categories; high, medium, and low, depending on the estimated impact.

Table 2.2 - Impact per Million Passengers

Estimate	Jobs		Economic impact* ($m)	
	Direct	All	Direct	All
High	2,000	7,500	200	1,500
Medium	1,500	6,000	70	600
Low	750	2,500	30	120

Source: Montalvo, Jose G. (1998). *A Methodological Proposal to Analyze the Economic Impact of Airports.* International Journal of Transport Economics. Vol.25(2), p.199, Table1.

* The economic impact corresponds to US airports only and is calculated in 1990 US dollars. When necessary the data is upgraded using US inflation index.

There are several other examples of how multipliers have been used to find the impact of numerous airports. There is a great difference in the estimated impact, but as has already been shown, this is to be expected. Pitfield (1979) showed that the multiplier effect was higher during the operational phase than during the construction phase of an airport because the construction phase relies greatly on outside inputs, such as outside contractors coming into the area. Further, Oster *et al.* (1997) found that the impact was higher if the airport served the system as a hub. Also, "many analysts agree that one of the most significant benefits of the great hub airports is indirect: the presence of a modern air hub encourages all kinds of businesses to expand or relocate. Air access is a top-ranking factor for many companies deciding where to build new facilities" (Massey, 1988, p.44). Several "aviation economists say that, on a per-flight basis cargo creates more economic benefits to a community than passenger service" (Fulton, 1991, p.39). It is therefore also very important to look at the indirect and induced economic impact, and not only the direct impact.

Dempsey *et al.* (1997) stated that an airport is the single most important piece of infrastructure for economic growth. Thus, one thing that should be kept in mind when estimating the economic impact of an airport is that the study might not capture the full effect because the impact does stop at the boundaries of the study area. This is probably the reason why Stapleton International Airport was often "referred to as the region's single most important economic asset" (Massey, 1988, p.60). The construction of a new airport in Denver was related to a number of anticipated economic benefits such as a boost to the economy due to

an increased number of international cargo and passenger flights, as new international routes would attract foreign businesses. It was also expected that 27,000 jobs would be created at the airport, and that there would be a demand for 1 million square feet of business space when the airport opened (Fulton, 1991). Further, additional tens of thousands of jobs would be expected and there would be a demand for many millions of square feet of business space prior to 2010 (Fulton, 1991). It is evident that airports do impact the surrounding area and serve as an accelerator to the economic activity in this area. Thus, it is often difficult to identify the impact uniquely caused by the airport since it varies from case to case. However, it is also this inherent complexity of the results that makes it interesting to look at the impact caused by airports.

Zoning

Different zoning boundaries are often established around airports to control the land use in order to limit the negative impact associated with airports. The most noticeable problem is that of airport noise, since this is not limited by the boundaries of the airport, and therefore affects the surrounding communities at varying degrees. In the early 20th Century, there were only a limited number of restrictions. This was mainly due to the fact that annoyances caused by noise were fairly limited. The concept of airport zoning was first introduced by many cities after World War II to control the land use at and around their airports (Bednarek, 2000). Prior to this period, there had been some restrictions, but

these were based mainly on the risk of aircraft accidents and not as much on the impact of noise.

The risk of accidents has not disappeared, but with the introduction of the jet engine the impact of noise has become more evident. The problems associated with noise are especially noticeable under the approach and take-off paths (Timmenga, 1979). In addition, the noise impact is not going to be uniform around the airport due to the configuration of the runways. There is thus a need for different zoning boundaries with compatible land uses defined for each specific area depending on the noise level. Compatible land use activities include agricultural, commercial, and industrial development, whereas residential development is considered a non-compatible land use. One approach would be to create zoning boundaries limiting the amount of residential development and encouraging compatible ones. Stratford (1974) stated that the establishment of agricultural land is the best way to minimize the negative effects created by an airport.

In the Netherlands, a set of well-defined zoning boundaries were adopted after the lack of such zoning boundaries had led to serious problems at the Schiphol airport. The problem was that at the same time the airport was constructing a new runway, a residential area was being built in the cardinal direction of the approach and take-off path of the new runway. A new zoning act was therefore adopted in 1978 in order to avoid similar mistakes in the future. The new zoning ordinance put limitations on the type of land development underneath the approach and take-off routes depending on the location in

relation to the airport (Timmenga, 1979). Similarly, in 1984 Las Vegas, Nevada adopted a comprehensive land use and zoning plan to regulate future development in order to minimize the negative impacts created by noise (Knack and Schwab, 1986). The plan was to identify potential problem areas, and regulate against certain land uses in those areas to avoid future problems.

Airports pull the development of their respective cities in the direction of the airport by mainly attracting non-residential land use development (OECD, 1975). This urban encroachment will later create problems when there is a need for an expansion of the airport capacity, because it leaves the airport with no room to grow (The airports' space squeeze, 1982). The lack of space together with local resistance often makes it hard for an airport to expand its capacity. In Denver, the lack of space and local resistance also created problems and finally led to the abandonment of Stapleton International Airport for a new site in neighboring Adams County.

Between 1986 and 1989 the city of Aurora, which is located just south of the new Denver International Airport, annexed approximately 70 square miles, doubling its size to 140 square miles (Weiss, 1989). These annexations pushed the borders of Aurora to the edge of the new airport site. This was done because of the expected economic growth the new airport would generate in the area. The city of Aurora developed a comprehensive land use plan in order to control this expected economic growth (Weiss, 1989). The hope was that the plan would help develop a better mix of land uses and control urban sprawl. This development led to the movement of the new "45-square-mile site several miles

to the northeast to protect large tracts of Aurora's newly annexed territory for housing" (Weiss, 1989, p.16).

A similar approach was used in the city of Kenosha, Wisconsin, where different zoning restrictions were put on the land use of up to three miles from a newly planned airport (Airport zoning needs ground landowners' right, 1998). The quest for a better mixed land use is a more recent one. Earlier developments focused on attracting hotels, motels, restaurants, cargo distribution, warehouses, and maintenance facilities. This type of activity is still important, but today there is a tendency to incorporate some residential development in order to create a more diverse land use. The best example of this is Las Colinas between Dallas and Fort Worth. Close to the Dallas/Fort Worth Airport, this area includes retail, recreational, educational, residential, and commercial development (Dempsey *et al.*, 1997). A more recent example of a comprehensive land use plan is that of Ørestaden in Copenhagen, which is a 310-hectare area just southwest of Kastrup Airport. The detailed plan for Ørestaden includes residential and commercial zoning ordinances, roads, railroads, subways, schools, a convention center, parks, greenbelts, open space, canals, wetlands, and other environmentally protected areas (Nilsen, 1995). A similar plan was developed in Denver for the area surrounding Peña Boulevard, the main access road of the airport (Dempsey *et al.*, 1997). As it has been shown, the main reason that planning departments go through the trouble of establishing these zoning boundaries is that cities want to control the development of its land to best serve the community as a whole.

Airport Noise and Property Values

The study of airport noise and its impact on the property market is a very well documented and well-researched area. The core of this research is based on the Hedonic pricing approach, which was developed by Griliches (1971) and Rosen (1974). This approach has become the standard in most studies, and is still taken into consideration in most other studies.

The Hedonic approach is the most common method in the analysis of the impact of noise on property values, and it measures the willingness to pay. The approach is a regression analysis that incorporates variables that determine the quality of the property. These are variables showing structural characteristics and accessibility to the property. Some of the structural characteristics include the number of rooms, number of bathrooms, the year of construction, number of square feet, and the type of exterior wall. The accessibility variables include access to public transport, access to public schooling, and the distance to the airport and central business district. The final variable is a measure of the economic impact of noise on the property market. The most common approach is to use a Noise Exposure Forecast (NEF), which is a cumulative noise representation combining the level and the frequency of noise associated with an airport (Levesque, 1994). While the NEF is the most common-used representation of noise in this type of study, it is not the only one (Tomkins *et al.*, 1998; Pitt and Jones, 2000). Results of the studies using the Hedonic approach are usually reported using the Noise Depreciation Sensitivity Index (NDSI), which

measures the cost of a one unit increase in the noise level. There are several examples of studies through time that have used this approach, which are mentioned in the following sections.

One of the pioneers in the study of property values related to airport noise is Jon P. Nelson, who conducted a number of studies in the late 1970s in which he attempted to clarify the relationship between airport noise and property values. In one study he used the Hedonic approach to compare census block data for six cities in the United States (Nelson, 1979). Nelson's study began with the assumption that people will be less and less satisfied the closer they live to an airport due to the increased noise exposure. The fact that major airports are large employers of people raises the following question: Is there a trade-off between the decrease in property value caused by the increased level of noise and the decrease in commuting cost by living in close proximity of the airport? The result of Nelson's (1979) study was that the value of residential property decreased when located closer to the airport. In the study, he did not conclude that the effect of the decreased commuting cost might affect the price, but said that there was not enough evidence in the study and that further research was needed.

Nelson (1980) then summarized the findings from thirteen studies, all of which used the Hedonic approach. The overall conclusion was a NDSI range of about 0.40 to 1.10 percent per decibel, indicating an average discount rate of about 0.61 percent per decibel (Nelson, 1980). Thus, a house located in a noisy area would be between 10 to 20 percent cheaper than an identical house located

in a non-noisy area. The methods developed by Nelson in these two articles have been used or quoted in many other works dealing with this issue.

For example, O'Byrne *et al.* (1985) used Nelson's method to compare two different data sources to determine if they produced comparable results. The two sets of data were census block groups and data from individual house sales. They were interested in whether or not census data was as reliable since it was a more crude measurement of reality. The study area was a neighborhood in Atlanta east of Atlanta International Airport. Census block data from 1970 was compared to individual sales data from 1979-1980. Using these two data sets produced a NDSI of 0.67 percent per decibel for the individual sales data and a NDSI of 0.64 percent per decibel for the block group data (O'Byrne *et al.*, 1985). These results show that there was a close similarity between the two data sets and that it was therefore hard to determine which one was the best. They therefore concluded that it was acceptable to use census block data when estimating the cost of airport noise. The result of this study was also comparable with the rates of depreciation found by Nelson in the 1970s. There was also a discussion of the work prior Nelson's because they tended to produce a larger level of depreciation. This might have been due to the fact that "the earlier period of travel by commercial jet was associated with a transitional period of adjustment in residential housing markets that had essentially ended by the late 1960s" (O'Byrne *et al.*, 1985, p.176). This is evident in a study by Paik (1972) in which a noise discount rate of 2 percent per decibel was produced using 1960 census block data. Thus far the studies have shown that there will be a level of

depreciation in the house value when affected by airport noise, but the next section will show this is not always the case.

The estimated impact of noise depreciation has decreased over time. For example, Pennington *et al.* (1990) felt that the noise level did not have as much effect on the prices of residential properties as previously expected and that the difference in price might be caused by other factors. This study also used the Hedonic approach, but used a different type of data. This data set was not based on census blocks or a survey, but was instead compiled from a complete data set for an entire neighborhood north east of Manchester International Airport. As in the previous studies, the result was a 6 percent reduction in the price from the worst affected area to an identical property somewhere else within the study area (Pennington *et al.*, 1990). The study then compared the neighborhood characteristics between the noise-affected and non-affected areas and determined that there was a significant difference between the two areas other than the level of noise. This indicated that there might have been other factors than the level of noise that created the difference in price. Through the recognition of these different neighborhood characteristics they concluded that the difference in property value between noise-affected areas and non-affected areas became statistically insignificant. This indicated that the properties within these neighborhoods "could still be expected to command lower prices even if they were not under the flight path of aircraft using the airport" (Pennington *et al.*, 1990, p.58). As a result there was some evidence that the noise impact might not be as high as thought earlier, even though this was the prevailing logic.

These previous studies were limited to looking at individually owned residential property. This changed in 1993 when Uyeno *et al.* used Nelson's approach but expanded it to include multiple-unit residential condominiums and vacant land. They used Nelson's approach for comparability, because they hypothesized that higher environmental concerns would have increased the depreciation of property influenced by noise. They found that the NDSI for individually owned property was 0.65 as compared to Nelson's 0.61. So there has been no significant change in the depreciation of property due to increased environmental concerns (Uyeno *et al.*, 1993). Further, a NDSI of 0.90 percent per decibel for multiple-unit residential condominiums was found. These results showed that the depreciation of this type of building was higher than that of individually owned property. It was also found that the depreciation for vacant land was significantly higher than the other two. This is expected because the construction of a building is the same whether or not there is a presence of noise, so the difference in price will be reflected in the cost of land (Uyeno *et al.*, 1993). The cost of construction material is relatively uniform indicating that price difference are reflected in the land cost, which might also be the why this type of study had not been undertaken prior to the study by Uyeno *et al.*

The Hedonic approach used in the previous studies was criticized in Levesque (1994) because of the lack of flexibility in the NEF. Specifically, since the NEF is a cumulative measurement of the noise level, it does not account for the difference in noise occurrences from place to place when applied to the model. He therefore suggested a different approach to measure the level of

noise that was then tested against other models. The result of this was an R^2 of 0.80 for the new approach. Compared with the other approaches it was concluded that statistically the new approach was more applicable (Levesque, 1994). Further, the finding "suggests that a constant background level of noise is more detrimental than one in which there is more variability" in the level of noise (Levesque, 1994, p.209).

All the previous studies can be seen as a study of the balance between cost and benefits, the cost being the noise and the benefits being the increased access, employment opportunities, or improved infrastructure. Most of the studies indicate that there is a cost of being in the area of a major airport, but there is some ambiguity regarding the differences in value from area to area. Pennington *et al.* (1990) found that the impact of noise on the property values nearly vanished when different neighborhood characteristics were taken into account. In relation, Tomkins *et al.* (1998) found that the negative effects caused by noise were balanced out by the positive benefits mentioned above.

Noise impact studies often become important before airports are expanded, because local communities are concerned with what will happen to the property if an expansion takes place. Examples of this are Pitt and Jones (2000) and Espey and Lopez (2000), who respectively looked at the impact of noise surrounding the airports in Manchester, England and Reno, Nevada. It should also be mentioned here that there are examples of studies that used a different approach. An example would be Bell (2001), who used a Detrimental

Conditions Matrix to estimate the noise impact. The finding of this study was comparable with the studies using the Hedonic approach.

Looking at the studies over time, research indicates that there has been a decrease in the depreciation of residential property over time. None of the previous studies, however, looked at the effect of noise on commercial property. The effect on this type of property would probably be limited because this is the type of development an airport would be expected to benefit. In addition, "the effect on commercial property is likely to be beneficial, whereas it will have an adverse effect on residential property in the short term" but that in "the long term, it is possible that local residential property prices will be pushed up by the presence of a major airport" (Pitt and Jones, 2000, p.497). The level of depreciation of property values appears to have decreased over time, which might the result of airports becoming an integrated part of our lives or due to the improvement in noise abatement.

Denver International Airport

The airport later known as Stapleton International Airport was built in 1929 seven miles from downtown Denver at a 640-acre plot of land for approximately $430,000. The main terminal was not much bigger than the terminal found at Stillwater Regional Airport, in Oklahoma, today. The airport was named Denver Municipal Airport, a name it kept until 1944 when the name was changed to Stapleton Airfield in honor of the 1929 mayor Benjamin Franklin Stapleton. The

name was later changed to Stapleton International Airport, a name it kept until its closing in 1995. At its initial construction in 1929 the airport was believed to be among the three best airports in America and "large enough and level enough to meet all future need of long-distance passenger flying from the standpoint of speed" and "of sufficient size to take care of several thousand arrivals and departures daily" (Noel, 1991, p.95). The airport was prophesized to be of great benefit to the otherwise isolated area of Denver. This was exactly the case and the airport was enlarged several times to meet increasing aviation demand through the 20th Century.

In the 1980s there was a need for a further expansion as the airport had grown to be the fifth busiest hub in the world. The constraints of the capacity combined with the airport's influence as a hub led to delays throughout the entire United States. The delays were magnified during periods of inclement weather due to the configuration of the runways, which made only one runway available during these periods (Dempsey *et al*, 1997). With its location only seven miles from downtown, the airport was now completely surrounded by the Denver metropolitan area. There was heavy resistance towards an expansion in the area surrounding the airport, with the increased noise pollution a larger airport would create. If Stapleton were to be expanded it would be to the north onto the Rocky Mountain Arsenal, a former chemical weapons production site. This site had been designated a Superfund site by the Environmental Protection Agency (EPA), and there was heavy opposition against operating an airport facility on that site (Dempsey *et al.*, 1997). Finally, there were also concerns about the new

runways being close to the existing development surrounding the airport. The Stapleton International Airport expansion was finally abandoned in the 1980s as the decision to build a new airport was made. It was determined that that the economic benefits would be greater for the Denver area if a new airport was built.

Construction began on September 28, 1989, after several years of intense debate over the project. Since 1974 there had been an increased push for an expansion of the capacity at Stapleton, especially from the Federal Aviation Association (FAA), since the airport had become a bottleneck for the entire system during severe weather. The original plan was to expand Stapleton International Airport onto the Rocky Mountain Arsenal north of the airport, but this plan was abandoned because it was estimated that it would cost upwards of $6 billion to clean up the site in order to make it suitable for operating an airport, compared to the $1.7 billion cost of a proposed new airport.

The development of a new airport came at a time when the economy and population growth of Denver had become stagnant. It was thus viewed by many as a desperately needed boost to the local economy. In 1986, it was estimated that ten percent of Colorado's income could be attributed to the Stapleton International Airport, and it was projected that this would increase if a new airport was built (Dempsey *et al.*, 1997). Also, it was believed that a new airport would create 90,000 new jobs and generate more than $8.2 billion in business revenue each year. The promise of more jobs and related economic growth led the voters of Denver to approve the construction of a new airport in 1989 (Knack, 1990). The citizens spoke clearly for the new airport with a vote of 63 percent to 37

percent (Church *et al.*, 1989). It was believed that the airport would be the second busiest airport in the world at its proposed opening in 1993 (Denver, 1988).

A 53 square mile area, 23 miles northeast of downtown Denver in neighboring Adams County, was chosen as the site of the new airport. The size of this area, two times the size of Manhattan, made it the "largest piece of real estate dedicated to commercial aviation on earth" (Dempsey *et al.*, 1997). The plan was to build an airport with 120 gates and 5 runways, expandable to 200 gates and 12 runways as future demand increased, enabling the airport to handle up to 200 million passengers a year. The airport would therefore be an airport of the 21st Century. The construction plan was changed several times due to problems and resistance to the project, especially the airline industry, thus increasing the cost of the project as time went on.

The modifications to the project increased the cost from $1.7 billion at the beginning of the project to $5.3 billion when it was finally finished. The main opposition against the new airport came from the major airlines operating at Stapleton, which included Frontier, Continental, and United Airlines. These airlines were not convinced that a new airport would serve their best interests. They were content with their present location and feared that other airlines would be able to enter their market area at a new airport. When construction started in 1989, Frontier had disappeared, having been absorbed by People Express, leaving only Continental and United Airlines. Their resistance to the project translated into a number of design changes of the terminal building in order for

the airlines to commit to the project. The most important of these changes was a fully automated baggage system that would speed up the time needed to transfer bags from one location to another. The automated baggage system contributed to a large share of the price increase, because it led to four postponements of the opening date. This baggage system has often been referred to as the "luggage-smasher" (Feldman, 2000).

Changes made to the rental car and cargo facility also increased the cost of the airport. To make problems worse, Continental decided to abandon Denver as a hub in 1994, which left United Airlines as the only major airline carrier there. As a result, the number of gates was decreased from 120 to 85. There was also an opposition from the public, which was mainly concerned with the cost of engaging in the project combined with environmental considerations such as noise pollution. There was also a concern regarding the size of the new airport, because it would heavily contribute to urban sprawl within the Denver metropolitan area (Dempsey *et al.*, 1997). The public opposition in a project like this can also be seen as a conflict of preferences, because most people want the convenience of having the airport close to where they live but they are not interested in having it in their backyard. These are all issues related to the construction of the airport that was originally scheduled to open in October 1993, but was first officially opened February 28, 1995. The most noticeable problem was the issue with the baggage system, which continued after the opening of the airport, increasing the final cost substantially.

In the development of the new airport it was always believed that the airport would stimulate economic growth in the Denver area (Fulton, 1991). Optimists believed that the new airport would attract both national and international investments to the area due to Denver's central location in the middle of the United States. An estimated 500 potential companies, mainly in telecommunications, computers and financial services were expected to move to the area (Denver's new airport, 1994). That it is high-technology industries there would be attracted to the new airport in Denver, is supported by a previous study that showed these are the type of industries that will make their location decision based on good air service (Goetz, 1992). So the air service to these companies becomes "an essential ingredient in their location decision" (Goetz, 1992, p. 219). The City of Aurora, a suburb east of Denver, was especially excited about the new airport before its construction, because the residents believed that it would greatly increase the city's tax base as companies located in the area surrounding the airport (Weiss, 1989). This is the case as Aurora has been successful in attracting communications and aeronautics firms to the area (Weiss, 1989).

CHAPTER III

DESCRIPTION OF STUDY

Research Purpose and Objectives

The purpose of this research is to quantify and explain the land use changes that occurred between 1990 and 2000 around Denver International Airport. This is done by analyzing of various socioeconomic variables obtained from the Census Bureau, and parcel information and zoning boundaries for the northern part of the City of Aurora. More specifically, this study addresses the following research questions:

1. Has there been a detectable change in the land use?
2. What type of new development has taken place?
3. Has there been a noticeable increase in the activities that can be logically attributed to the presence of the airport?
4. Has the airport had a positive effect on the areas close to the main entrance and a negative effect in areas further away, especially those affected by the noise produced by the airport?

Scope of Study Area

The study area for this research is located within Adams, Arapahoe, and Denver counties in the state of Colorado. The Denver International Airport has an area of fifty-three square miles, and is twenty-three miles northeast of

downtown Denver in neighboring Adams County. Figure 3.1 portrays the airport, including the runways, in relation to the urban boundary of Denver. The Organization for Economic Co-operation and Development (OECD) stated in 1975 that when an airport is constructed outside a city, as was the case in Denver, the development of that city would be pulled in that direction by attracting compatible land uses. The most noticeable land use change should therefore be detected in the area southwest of the airport site, since this is the area between the airport and the city of Denver.

Selection of the size of the study area for the analysis of the census blocks surrounding the airport, and the analysis of the parcel and zoning information for Aurora is of great importance. The selected study areas should mainly incorporate areas directly affected by the presence of the airport. This is critical, because the goal is to show the impact of the airport, and not some external factor.

The study area for the analysis of the census blocks is comprised of the census blocks that are within a 10-kilometer radius of the perimeter of the airport, chosen at the author's discretion. Figure 3.2 portrays the extent of the census blocks used in this study when the 10-kilometer buffer is applied to these data. Figure 3.2 also shows the extent of the noise and height boundary for the airport, which further justifies the buffer size since these are almost perfectly contained within the buffer zone.

The study area for the analysis of the zoning boundaries and parcel information is comprised of the northern portion of the City of Aurora within

Figure 3.1 – Denver Metropolitan Area in Relation to the Denver International Airport

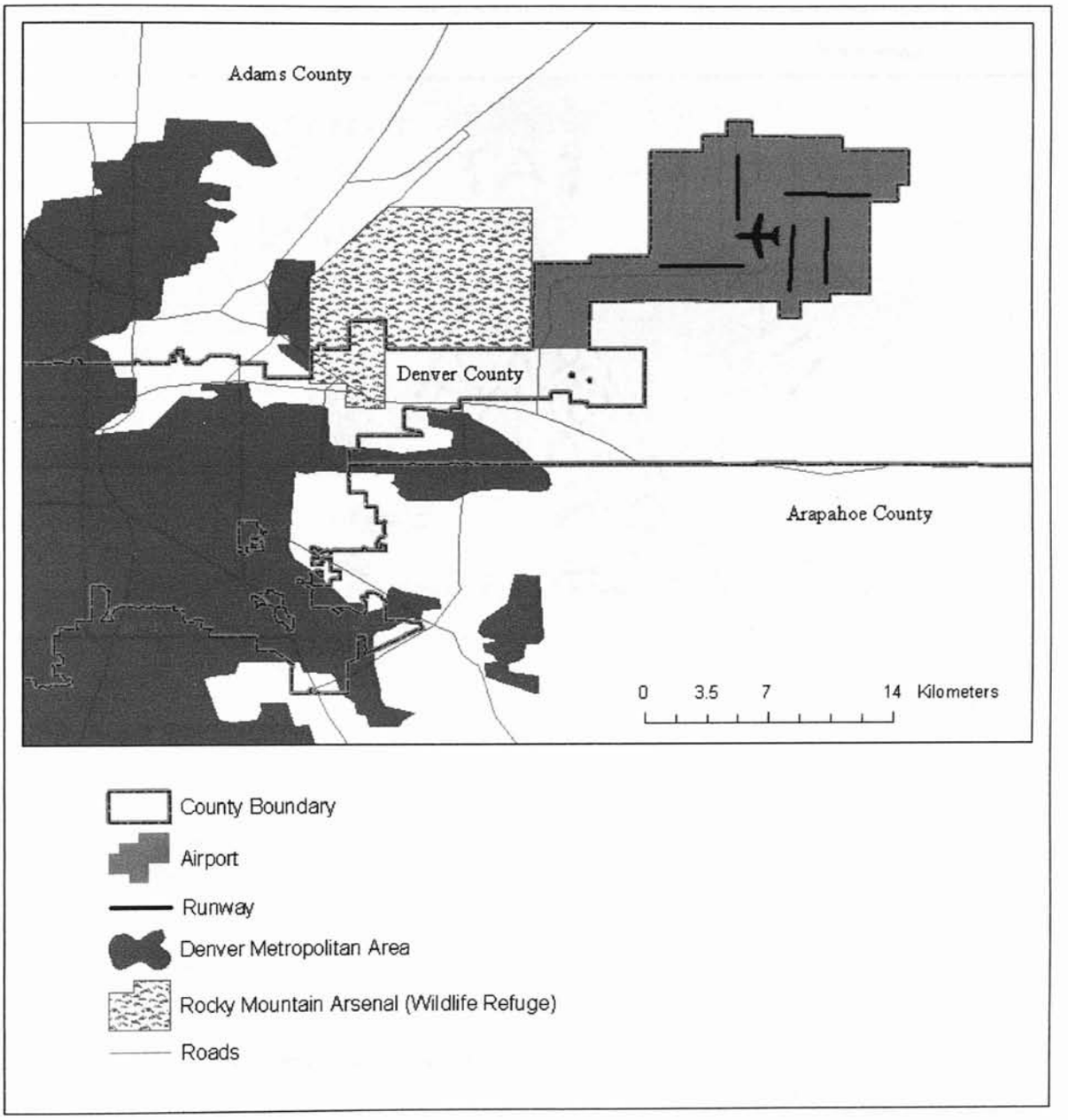
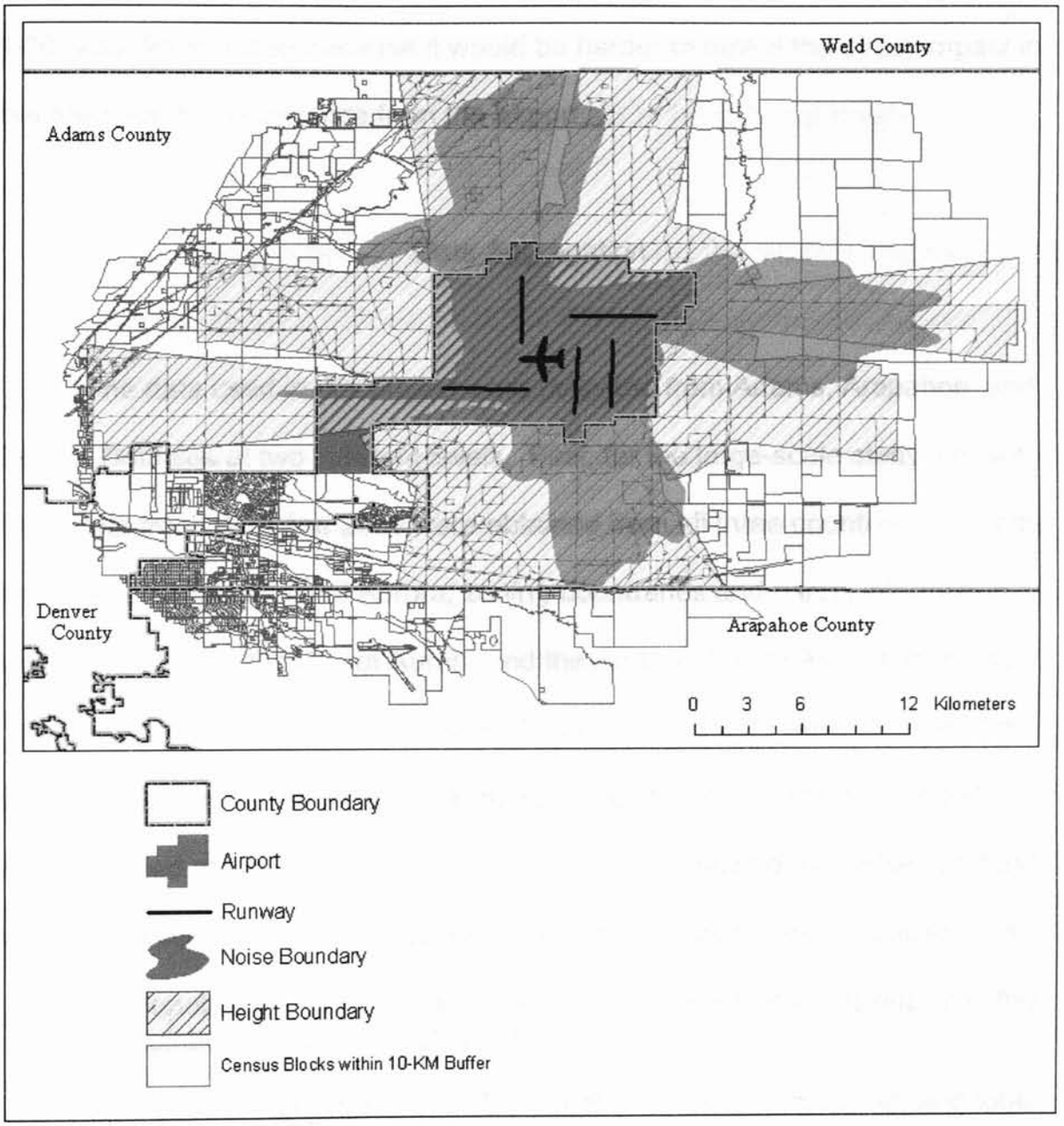


Figure 3.2 – Census Blocks within 10-kilometer Buffer Zone and the Airport Noise and Height Boundaries



Adams County. This study area was found appropriate since it is within the 10-kilometer buffer used in the previous sections. The area south of Interstate 70 (I-70) was not included because it would be harder to detect the direct impact in this area due to the distance from the airport.

Data Aggregation

The data used in this project were collected from Adams, Arapahoe, and Denver Counties at two different levels. First, for the large-scale study, census block data from 1990 and 2000 were obtained from all three counties. Secondly, for the small-scale study of Aurora, zoning boundaries and parcel information was obtained from the City of Aurora and the Adams County Assessors office.

Available 1990 and 2000 United States Census data were obtained from the 2000 Census CD for Adams, Arapahoe, and Denver Counties. The data were obtained at the census block level due to the smaller geographies of these areas. The census data included the following socio-economic characteristics:

1. Population – The number of people within each ethnic group, and the number of adults and children.
2. Housing Characteristics – The number of vacant, occupied, and total number of housing units.

Research using these demographic characteristics is used in the interpretation of the general land-use change surrounding the Denver International Airport.

The zoning boundaries used in the analysis of the impact in Aurora were obtained from the City of Aurora, and the parcel information was obtained from

the Adams County Assessors Office. The zoning boundary and parcel information was provided in a shapefile format, which made it easy to visually display the data using ArcGIS. The reason for obtaining this information was to help in the interpretation of what had happened in the area just south of the airport since 1990.

Other data sets used in this research included the airport noise and height boundaries, which were obtained from the Planning Department in Adams County. These two boundaries are used to explain differences in the land use characteristics surrounding the airport. The Adams County Planning Department further provided the zoning boundaries for all of Adams County, which was used to determine the zoning of the land surrounding Aurora not annexed by the City of Aurora.

Data Manipulation

Population Change

Table 3.1 illustrates the mean number of people per census block in 1990 and 2000, within the 10-kilometer buffer zone. It is evident that there has been an increase in the number of people, but the question is whether this change between the mean values for each variable is significant. A matched-pairs t-test is applied in this study, since a specific number of census blocks were selected as the sample size but at two different times. Since this is the measurement of a

TABLE 3.1 – Average Population per Census Block

Census Variable	1990	2000
Total Population	33.68	50.15
Adult	24.25	35.09
Non-Hispanic	29.82	32.85
White	23.19	27.14
Non-Hispanic Adult	21.76	24.19
Hispanic	3.86	17.30
Children	9.43	15.05
Hispanic Adult	2.49	10.91
Black	7.83	10.53
Non-Hispanic Children	8.06	8.66
Other	1.28	8.08
Hispanic Children	1.37	6.39
Asian/Pacific	1.05	1.50
Native American	0.34	0.57

before-and-after situation, the two sample means are considered to be from a dependent sample (McGrew and Monroe, 2000). The matched-pairs procedure is therefore the correct test, to determine the significance of the difference between the mean values. The equation used to derive the t-value for the matched-pairs is defined as:

$$t = \frac{\bar{d}}{\sigma_d} \tag{3.1}$$

where $\bar{d}$ = mean of matched-pairs difference (d)
σ_d = standard error of mean difference

The numerator of equation 3.1, the mean of the matched-pairs difference (d), is defined as:

$$\bar{d} = \frac{\sum d_i}{n} \tag{3.2}$$

where d_i = difference for matched-pairs i
n = number of matched pairs

The denominator of equation 3.1 is the measurement of the standard error of the mean difference in the matched pairs:

$$\sigma_d = \frac{S_d}{\sqrt{n}} \tag{3.3}$$

where

$$S_d = \sqrt{\frac{\sum (d_i - \bar{d})^2}{n-1}} \tag{3.4}$$

The final part of the matched-pairs t test derives the p-values for each variable in order to determine the statistical significance of the difference. The results of the matched-pairs calculations are summarized and discussed in the next chapter.

The strength of the relationship between the 1990 variables to their respective 2000 values can also be tested through a correlation analysis. The first part of the correlation analysis checks the direction and the strength of the association between the 1990 and 2000 value for each variable. A Pearson's correlation product-moment is used.

The r-value is found by the formula:

$$r = \frac{\left[\sum (X - X)(Y - Y)\right] / N}{S_X S_Y} \tag{3.5}$$

where r = Pearson's correlation coefficient
N = number of paired values
$S_X S_Y$ = standard deviation of X and Y

Equation 3.6 is used to derive the t-value for the correlation analysis in order to test the statistical significance of the variables:

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}} \tag{3.6}$$

The results of the correlation coefficient calculations are summarized and discussed in the next chapter.

The last part of the analysis of the population change surrounding the Denver International Airport consists of a visual interpretation of the spatial distribution of the population within each ethnic group through the production of a series of maps. For each map the percent change within each census variable from 1990 to 2000 is calculated as:

$$Percent\_change(\%) = \left(\frac{(2000value - 1990value)}{1990value} \right) \times 100 \tag{3.7}$$

One issue to be addressed when calculating the percent change is the problem of dividing by zero. First, if a variable does not have any population in either year, the block is assigned a value of zero. Second, if there had been an increase from zero the block is assigned a value of 20000, which is greater than the largest increase within any of the variables. In addition, if a variable decreases to zero it is assigned the value of -101. On each map the data are categorized according to the following distribution:

- Decreased to zero – The block that had a population in 1990 but none in 2000
- Decrease – The blocks with a decrease in the population
- No change – The blocks with no population, or blocks with no change between 1990 and 2000.
- Low increase – Lower one third of the blocks with an increase
- Medium increase – Middle one third of the blocks with an increase
- High increase – Upper one third of the blocks with an increase
- Increased from zero – The blocks that had a population in 2000 but none in 1990

A visual interpretation of the maps is used to detect any notable population patterns within the 10-kilometer buffer zone. The results are discussed in Chapter IV.

Housing Occupancy and Vacancy

The next part of the analysis of the area surrounding the Denver International Airport examines the relationship between the residential vacancy

rate and the airport noise and height boundary of the airport. The noise boundary is defined as the area lying within the 60 Ldn (level at day and night) or greater noise contour isoline, whereas the height boundary is defined as the area where the allowed height of structures and natural features are influenced by the activities at the airport (Adams County, 2002). The housing data were obtained from the 2000 Census, and include the number of occupied, vacant, and total number of housing units. The data used in this analysis includes the 2956 census blocks within the 10-kilometer buffer of the airport. The percent of vacant housing units is calculated in order to better see the spatial variation within the study area. A series of maps are produced of the height and noise boundary overlaying the housing data classified by quintiles. Visual interpretation of the maps allows one to examine the relationship between the residential vacancy rate and the airport, the results of which are discussed in Chapter IV.

Land Use Change in Aurora

In order to investigate whether the establishment of the Denver International Airport had a significant economic impact on the surrounding area, the City of Aurora was chosen as a case study since it was projected that this area would greatly benefit from the new airport. It was predicted that the airport would create the demand for one million square feet of business space when it opened, and an additional demand of several millions of square feet of business space over the next two decades (Fulton, 1991). In order to test this, parcel

information was obtained from the Adams County Assessors office, and categorized by what each property was built as (Appendix A). The data are summarized into 101 categories, of which twenty were determined by the author to have a possible relationship to the presence of the airport (see Table 3.2). This not to say that all the activities within these categories are uniquely related to the airport, but that they are the type of activity one might expect to be linked to the activities at the airport. The study is divided into two different sections looking at the significance of the change.

TABLE 3.2 – Land-Use Categories Possibly Related to the Presence of the Denver International Airport

Built As	Land-use
Distribution Warehouse	Commercial
Distribution Warehouse	Industrial
Fast Food Restaurant	Commercial
Hotel - Full Service	Commercial
Hotel - Full Service	Industrial
Industrial Engineering & Research	Industrial
Industry Light Manufacturing	Commercial
Industry Light Manufacturing	Industrial
Mini Warehouse	Commercial
Modular Office	Commercial
Motel	Commercial
Office Building	Commercial
Office Building	Industrial
Parking Lot	Commercial
Restaurant	Commercial
Storage Warehouse	Commercial
Storage Warehouse	Industrial
Transit Warehouse	Commercial
Warehouse Showroom Store	Commercial
Warehouse Showroom Store	Industrial

The first part of this study is to determine if there has been a significant increase in the activities that were projected to have a possible relationship to the presence of the airport. This is done through a comparison of the changes within the compatible land use categories before and after 1990. Two equal time periods are selected, 1979 to 1989 and 1990 to 2001. This is done to see if a significantly larger percentage was built in the 1990s as opposed to the previous decade. If a larger percentage of the total number of parcels have been constructed after 1990, it would be possible to conclude that the airport had a significant role in the area since it was constructed during this period. The 101 original parcel categories are summarized into fifty-four categories, Appendix B. The rationale for this decrease in the number of categories is due to the fact that no distinction is made to the individual subcategories within the agricultural, exempt, and residential land use categories.

The second part of the study is a statistical test of the significance of the change in land use. It would be expected that the proportion of compatible land use has increased, if the airport has had a significant economic impact on Aurora. Since the expected economic activities that could be attributed to the presence of the airport are within either the commercial or industrial land use categories, it is predicted that there will be a significant difference between these and especially the residential land use category. A two-sample difference of proportions test is applied in this study to test the significance of the change in the proportion of parcels between the industrial, commercial, residential, and exempt land use categories. A series of tests are run, a separate test for each

possible pair of the four land use categories. The equation used to derive the Z-value for the two-sample difference of proportions test is defined as:

$$Z = \frac{p_1 - p_2}{\sigma_{p_1 - p_2}} \tag{3.8}$$

where p_1 = proportion of sample one in the category of focus
p_2 = proportion of sample two in the category of focus
$\sigma_{p_1 - p_2}$ = standard error of the difference of proportions

The denominator of equation 3.8 is the measurement of the standard error of the difference in proportions (McGrew and Monroe, 2000):

$$\sigma_{p_1 - p_2} = \sqrt{\hat{p}(1-\hat{p})\left(\frac{n_1 + n_2}{n_1 n_2}\right)} \tag{3.9}$$

The pooled estimate, $\hat{p}$, is the proportion in the focus category if the two samples where combined into one sample, and is defined as:

$$\hat{p} = \frac{n_1 p_1 + n_2 p_2}{n_1 + n_2} \tag{3.10}$$

The final part of the-sample difference of proportions test derives the p-value for each pair of variables in order to determine the statistical significance of the differences. The result of these calculations will be discussed in the following chapter.

The development of new parcels is closely tied to the present zoning boundaries. Therefore, the first analysis of the land use change in Aurora is an analysis of the zoning boundaries within the area in question. This is done to see if there is a unique zoning pattern that might help explain any change that occurred in the distribution of parcels between 1990 and 2000.

The result are summarized in a number of tables, which are discussed in Chapter IV together with a number of maps produced to visually identify any unique spatial patterns in the area just south of the airport.

CHAPTER IV

DATA ANALYSIS AND INTERPRETATION

This chapter provides the results and analysis of the study. Each section uses the analysis methods discussed in Chapter III, and utilizes the data collected for this study to address the research questions.

Population Change

Analysis

Three different approaches are used in the analysis of the population change surrounding the Denver International Airport. A two-sample Matched-pairs difference of means test (Equation 3.1) and a correlation analysis (Equation 3.5) are used to determine the significance of the relationship between the population data. The use of these two statistical methods further identifies the variables where the most significant change has occurred over the study period. The final part of the population change analysis is a map interpretation of the spatial change in the population surrounding the airport between 1990 and 2000. A total of 2956 census blocks were selected after the 10-kilometer buffer zone, previously discussed, was applied to the entire number of census blocks in

Adams, Arapahoe, and Denver County. The demographic variables selected for the research included:

1. Total population,
2. Asian/Pacific, Black, Hispanic, Native American, Non-Hispanic, White and Other population, and
3. Adult, children, non-Hispanic adult, non-Hispanic children, Hispanic adult and Hispanic children.

Results

The first part of the analysis of the population change was to determine the statistical significance of the population growth in the area surrounding the Denver International Airport between 1990 and 2000. One way of testing the significance of the population change is to use a matched-pairs t test. As already shown in Table 3.1, the mean population increased for all 14 variables used in this analysis, but what is the significance of this change? The null hypothesis for this problem stated that the population in 1990 was not significantly lower than the population in 2000. Table 4.1 summarizes the result of the matched-pairs t test. From this descriptive statistical analysis of the population data, it is evident that the study region has experienced a significant population change between 1990 and 2000. Since it was already known that the population had increased for all the variables used in this analysis, a one-tailed hypothesis test was chosen as the most appropriate. As shown in Table 4.1, all matched-pairs t-values are

TABLE 4.1 – Summary of Matched-Pairs t Test

Census Variable	t-test	p-value
Hispanic Children	18.356	0.000
Hispanic	17.090	0.000
Other	16.795	0.000
Hispanic Adult	15.887	0.000
Children	14.387	0.000
Total Population	13.159	0.000
Adult	11.806	0.000
Black	7.649	0.000
Native American	7.215	0.000
White	6.028	0.000
Asian/Pacific	5.959	0.000
Non-Hispanic Adult	4.010	0.000
Non-Hispanic	3.877	0.000
Non-Hispanic Children	2.714	0.003

greater than 2.714, which leads to corresponding one-tailed p-values of less than 0.004. Given these p-values, it is concluded that the change in the population is of statistical significance, and the null hypothesis is therefore rejected. When this result is compared to Table 4.2, the percent change within each group, it is evident that that the variables with a high t-value are also the variables with the highest percent change. This makes sense, because there is a direct relationship between an increase in the population difference and the t-value.

Table 4.2 shows that the census variable Other was the one that increased the most. Some caution must be taken before drawing this conclusion due to the change in the way the Census Bureau collected the 2000 data. The change made between the 1990 and the 2000 Census was that each person could declare more than one ethnic orientation. Thus, the large increase in the category Other is almost certainty caused by a large number people selecting

TABLE 4.2 – Summary of Total Population Change

Census Variable	1990	2000	Change(%)
Other	3777	23880	532.2
Hispanic Children	4057	18898	365.8
Hispanic	11412	51141	348.1
Hispanic Adult	7355	32243	338.4
Native American	999	1695	69.7
Children	27871	44496	59.6
Total Population	99547	148232	48.9
Adult	71676	103736	44.7
Asian/Pacific	3095	4422	42.9
Black	23139	31120	34.5
White	68537	80224	17.1
Non-Hispanic Adult	64321	71493	11.2
Non-Hispanic	88135	97091	10.2
Non-Hispanic Children	23814	25598	7.5

Other in addition to their specific ethnic group, because they did not feel that they completely belonged within that group. The variable Other will therefore not be discussed further in this investigation. What Table 4.2 does show is that the total population increased 48.9 percent, and that the majority of this increase can be contributed to a large increase in the Hispanic population. In relation, the non-Hispanic population is the one that experienced the smallest increase, especially the category White, which did not see much of an increase. Since natural growth over ten years makes significance difference almost a certainty, another way to statistically compare the change between 1990 and 2000 is the use of correlation analysis.

A Pearson's correlation analysis is applied to the population variables within the 10-kilometer buffer to determine the spatial association between the variables. A scatterplot of the 2956 census blocks of each 1990 population

variable is plotted against its respective 2000 variable. Figure 4.1 illustrates the association between the total population, whereas Figure 4.2 illustrates the relationship between the Hispanic populations in the two years. If these two scatterplots are examined more closely it is evident that there is a stronger temporal association in the total population than in the Hispanic population. Figure 4.1 further shows that there is a positive direct relationship between the two variables. It is therefore expected that the correlation results would be higher for the total population than that of the Hispanic population.

The null hypothesis states that no association exists between the population in 1990 and the population in 2000 within the 10-kilometer buffer zone. The alternative hypothesis states that a positive direct relationship exists between the variables. Since the direction of the correlation is hypothesized as positive, a one-tailed test is appropriate. Table 4.3 summarizes the result of the Pearson's correlation analysis. The difference in the resulting r-values indicates a greater change between 1990 and 2000 for the variables with the lowest r-values. The correlation is statistically significant for all the variables with a p-value of 0.000, and the null hypothesis is therefore rejected. If we look closer at the individual values in Table 4.3, we can see that the total population has a higher correlation value than that of the Hispanic population. This was expected since there was a closer association between the total population than the Hispanic population. It is also evident that the greatest change was seen in the Hispanic population and the least change in the non-Hispanic, especially the Black and White population.

Figure 4.1 – Scatterplot of Total Population

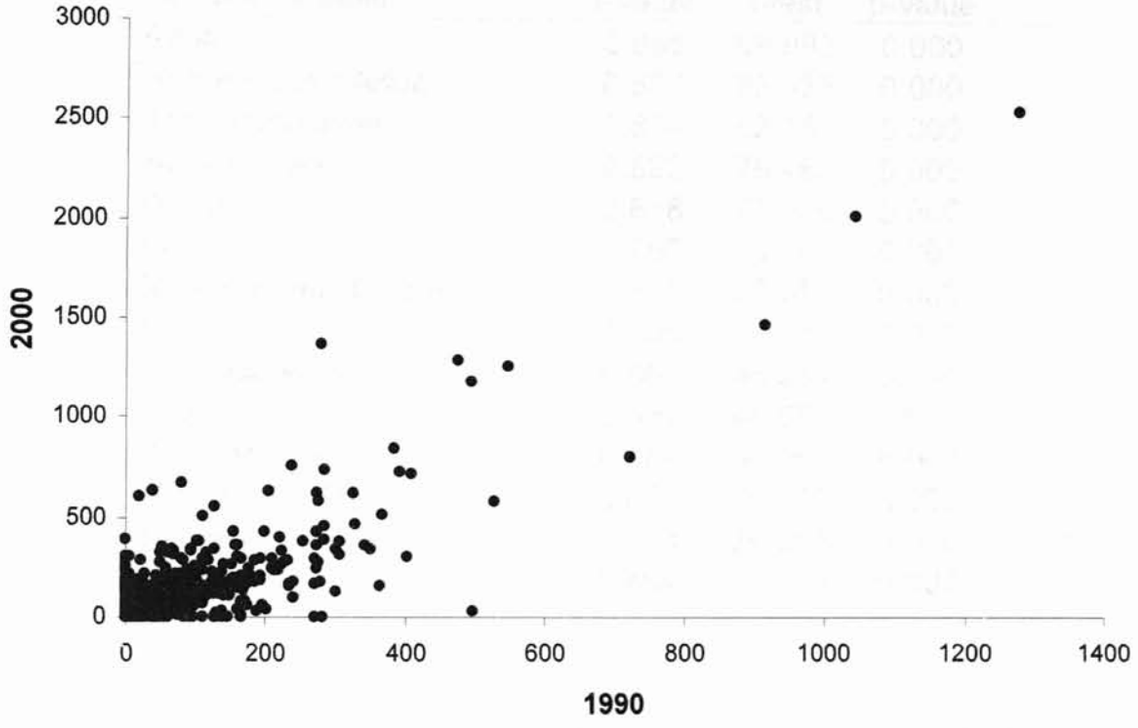


Figure 4.2 – Scatterplot of Hispanic Population

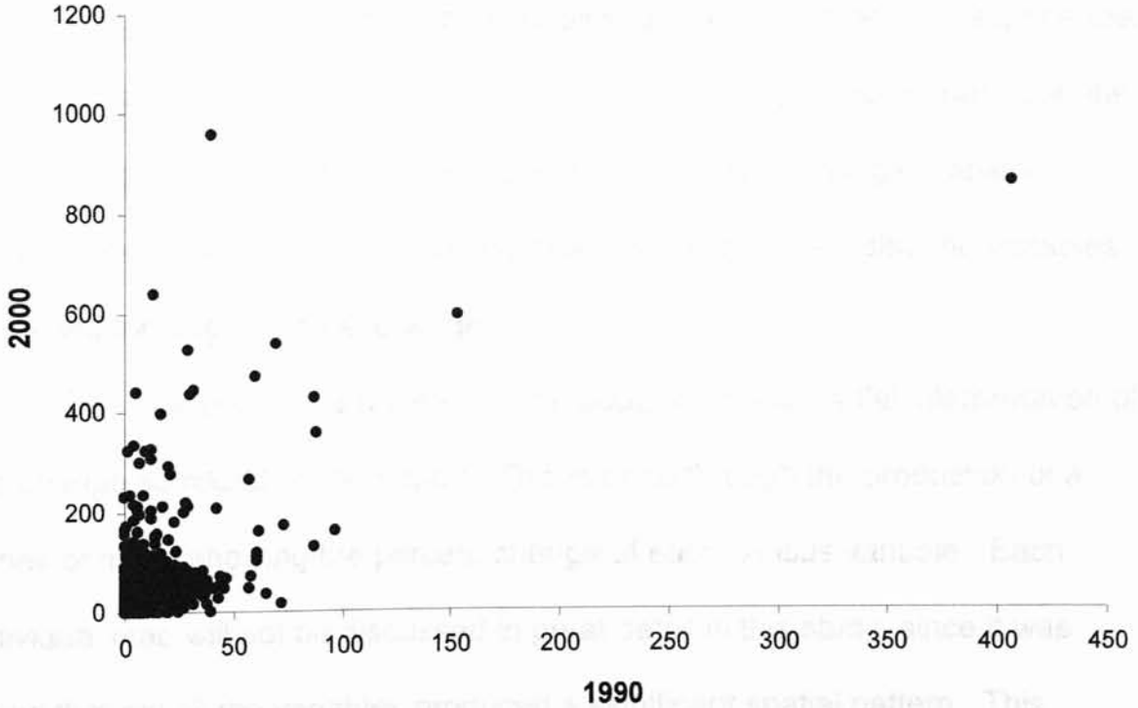


Table 4.3 – Summary of Pearson's Correlation Coefficient

Census Variable	r-value	t-test	p-value
Adult	0.856	89.993	0.000
Non-Hispanic Adult	0.837	83.135	0.000
Total Population	0.834	82.152	0.000
Non-Hispanic	0.822	78.450	0.000
Black	0.818	77.290	0.000
White	0.798	71.968	0.000
Non-Hispanic Children	0.759	63.359	0.000
Children	0.746	60.884	0.000
Hispanic Adult	0.664	48.264	0.000
Hispanic	0.599	40.657	0.000
Asian/Pacific	0.484	30.061	0.000
Native American	0.475	29.338	0.000
Hispanic Children	0.474	29.258	0.000
Other	0.464	28.469	0.000

A comparison of the two-sample difference of means test and the correlation analysis demonstrates a similar trend between the results. Both test shows that the Hispanic population variables are the ones that have experienced the most significant change, whereas the non-Hispanic population has seen the least change. This result also corresponds with the total change, Table 4.2, because the variables that statistically changed the most are also the variables there had the largest actual change.

The final part of the analysis of the population is a spatial interpretation of the change surrounding the airport. This is done through the production of a series of maps showing the percent change of each census variable. Each individual map will not be discussed in great detail in this study, since it was found that not all the variables produced a significant spatial pattern. This indicates a great diversity in the ethnic distribution of the population.

Figure 4.3 shows the higher population density west and southwest of the airport, as of 2000, which is what would be expected since this is the area towards the metropolitan area of Denver. The figure also show that there are no or very few people living within the immediate vicinity of the airport. It can also be seen that the Rocky Mountain Arsenal, a 27 square mile Wildlife Refuge, stands as a physical barrier to urban development within the study area. This should be kept in mind in the following interpretations of the study area because none of the examined land use characteristics will be evident within this area.

Figure 4.4 shows the population change surrounding the Denver International Airport between 1990 and 2000. It is obvious that there is not a distinct pattern when the entire area is examined as a whole, since there is not one area where there has been a distinct increase in the population and vice-versa. Except for the fact that the population of the blocks bordering the airport only increased within one block, which would be expected since most people more than likely have an apprehension against moving into an area bordering the airport. In addition, there are areas in close proximity to the airport that have had an increase in the population, but this is mainly in the less densely populated part of the study area. There has been a general decrease in the population of the northwest and southeast with some exceptions, but here it should be kept in mind that this is within areas of low population density.

If a closer look is taken at the more urbanized southwest, it is evident that there has been both an increase and a decrease in the population within this

Figure 4.3 - Population Density Within 10-Kilometer Buffer Zone

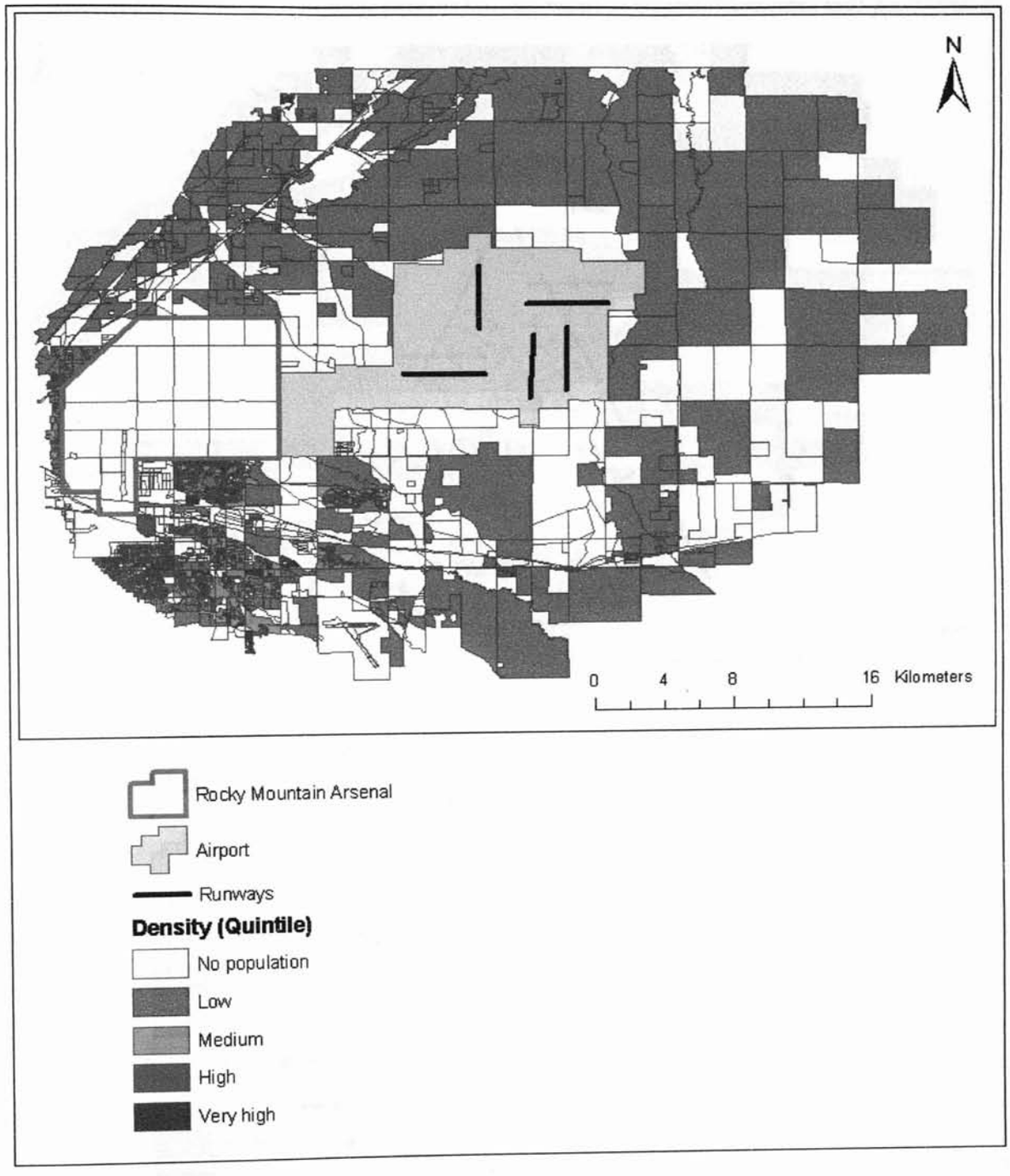
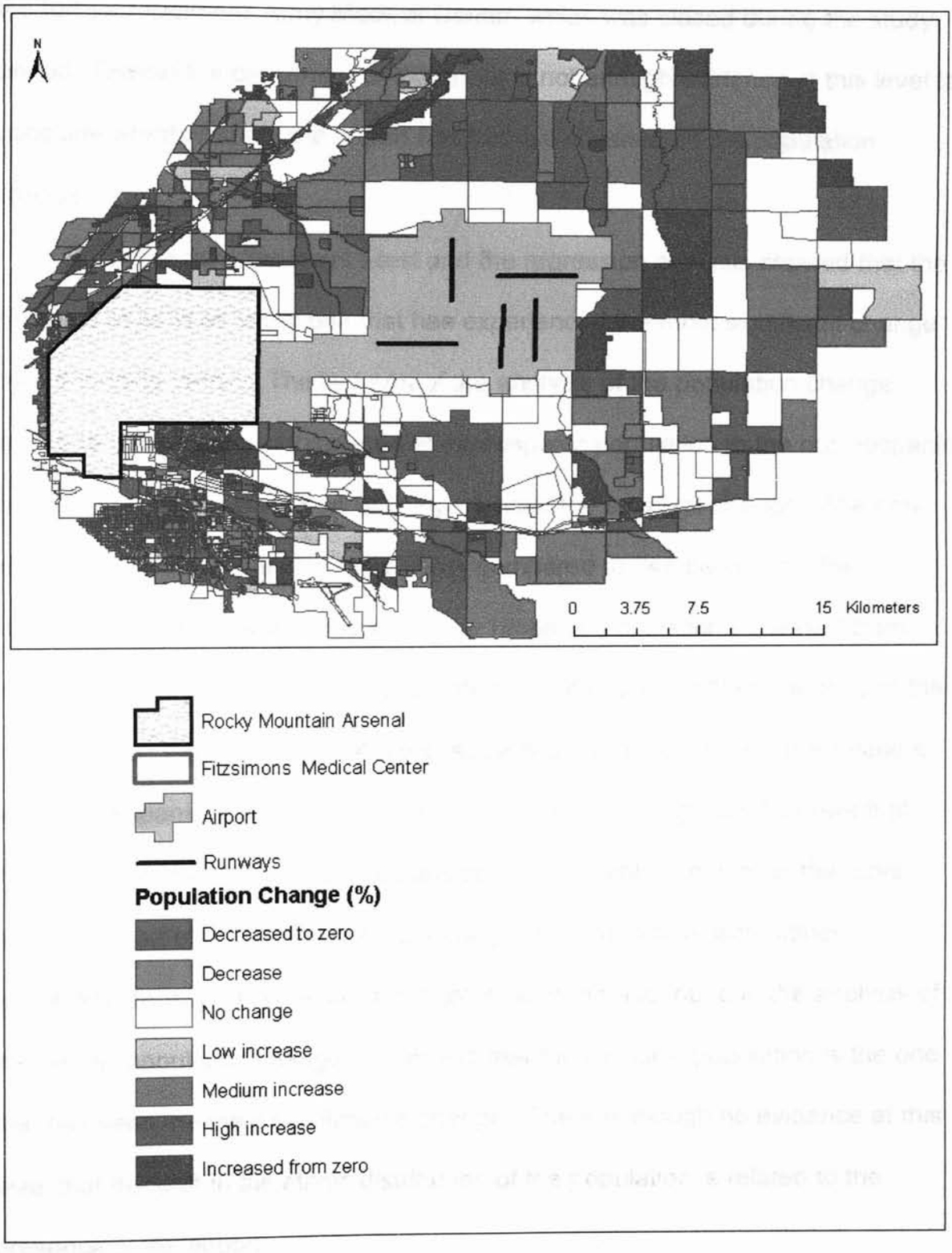


Figure 4.4 – Total Population Change



area. The most noticeable change here is the decrease in the population within the former Fitzsimons Army Medical Center, which was closed during the study period. Overall the consensus is that there is not enough evidence at this level to conclude whether or not the airport has had an influence on the population change.

Both the matched-pairs t-test and the regression analysis showed that the Hispanic population is the one that has experienced the most significant change over the study period. The last part of the analysis of the population change therefore consists of a comparison of the Hispanic population to the non-Hispanic population, which is the group that experienced the smallest change. The non-Hispanic population grew by ten percent compared to 348 percent for the Hispanic population (see Table 4.2). The Hispanic population increased from about eleven percent of the total population in 1990 to more than one third of the total in 2000. Figures 4.5 and 4.6 respectively show the change in the Hispanic and non-Hispanic population between 1990 and 2000. Figure 4.5 shows that the large increase in the Hispanic population has mainly occurred in the more urbanized part of the study area, especially within the blocks with higher population density. This result is consistent with the one found in the analysis of the overall population change, confirming that the Hispanic population is the one that has seen the most significance change. There is though no evidence at this level that the shift in the ethnic distribution of the population is related to the presence of the airport.

Figure 4.5 – Hispanic Population Change

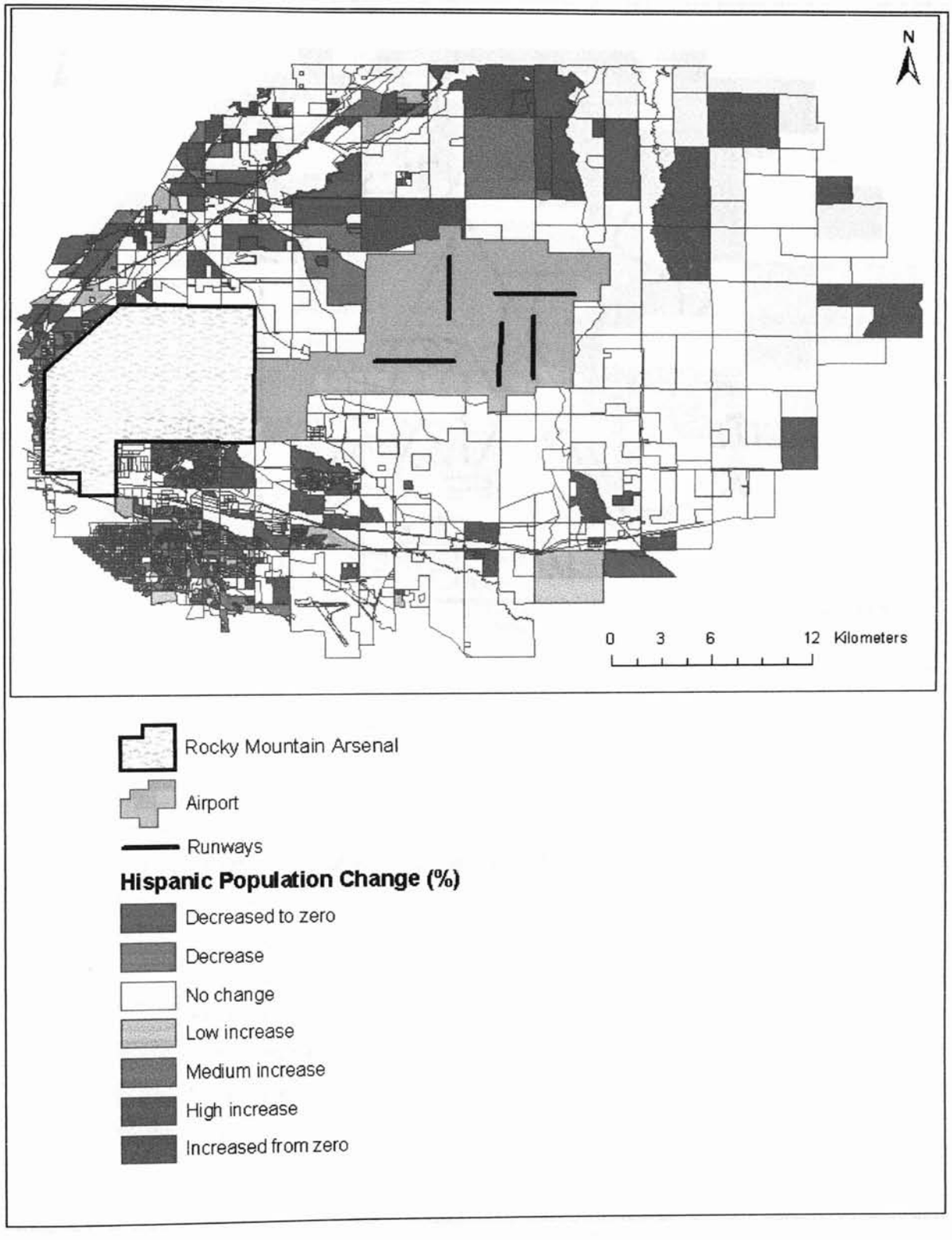
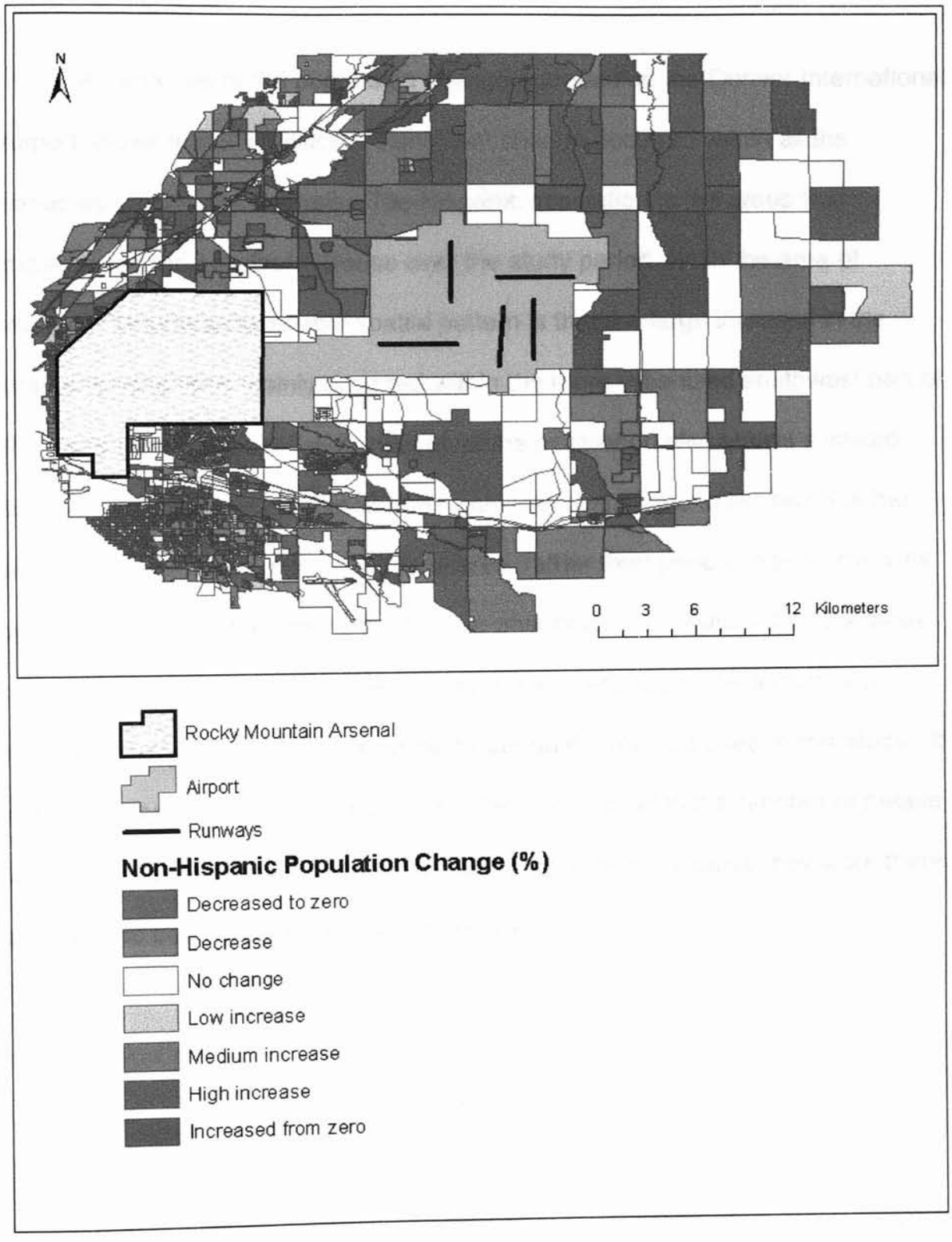


Figure 4.6 – Non-Hispanic Population Change



Summary

An analysis of the population change surrounding the Denver International Airport shows that a statistically significant change occurred within all the variables used in the analysis. The Hispanic population is the group that experienced the greatest increase over the study period within the area of interest. The most noticeable spatial pattern is that the large increase in the Hispanic population mainly occurred within the more urbanized southwest part of the study area. The spatial distribution of the population also shows a limited number of people close to the airport. This is probably due to the fact that the airport was constructed in a fairly rural area, rather than people leaving the area as a result of the airport being there. The population increased within the study area, but to what degree this was related to the presence of the airport or a natural increase can not be determined through the method used in this study. It should be mentioned here that other studies have found that a number of people will move to the area due to the presence of the airport, because they work there and want to be in close proximity to their work.

Housing Occupancy and Vacancy

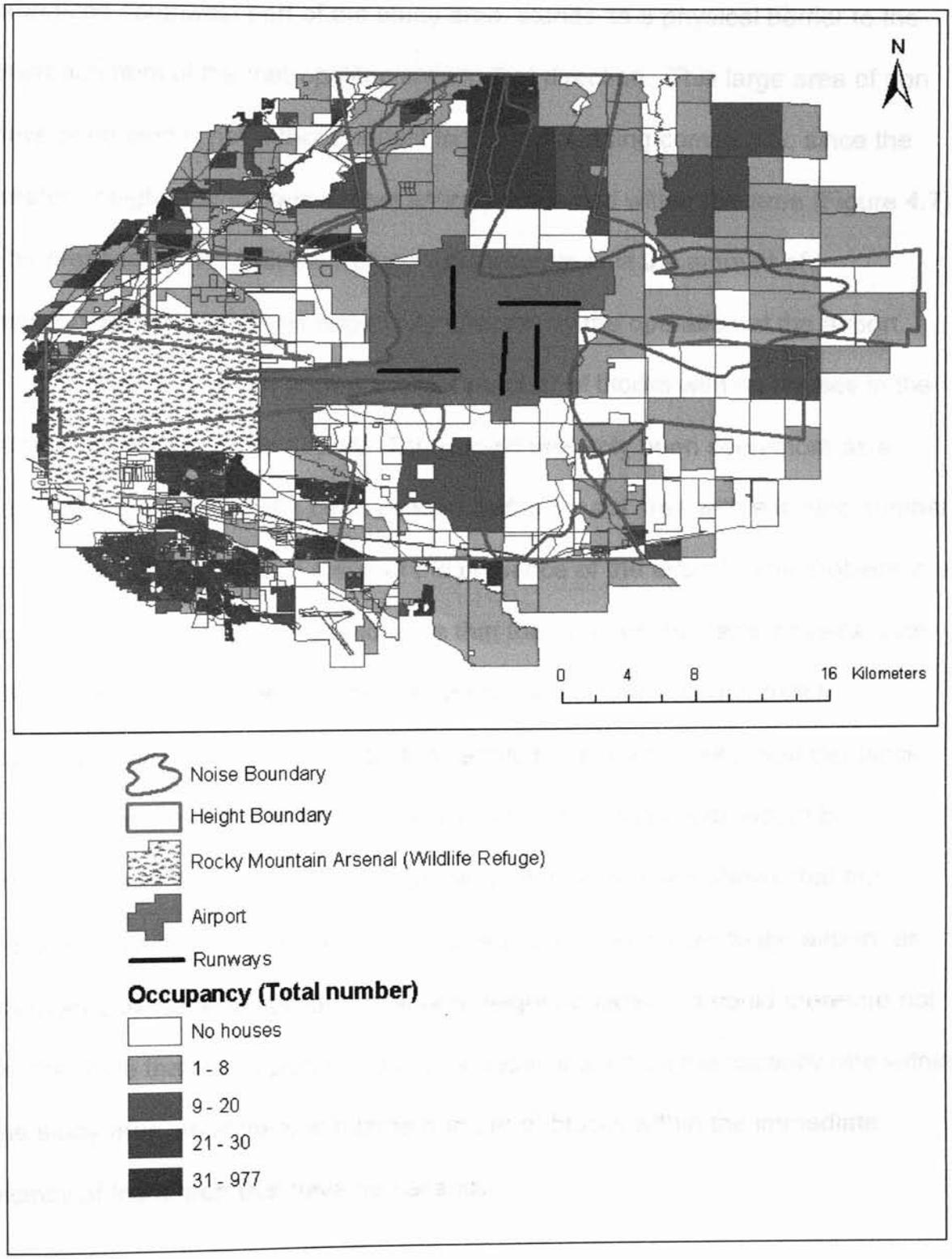
Analysis

The approach in this part of the study is to compare the noise created by the airport to the surrounding housing characteristics. This is done through a comparison of the number of vacant and occupied housing units to the area of immediate negative impact. It is expected that there will be a noticeable difference between the housing characteristics within the noise and height boundary as compared to the area outside. The census variables used for this study include the total number of housing units, number vacant, and number occupied. The sample size includes the same 2956 census blocks as used in the previous section.

Results

Figure 4.7 illustrates the total number of housing units mapped against the area directly impacted by the airport noise and height boundary. The figure shows a larger number of housing units in the southwest as compared to the rest of the study area. This is the same pattern as found in the analysis of the population density (Figure 4.3). This is not unexpected since there is a direct relationship between the number of people and the number of houses in an area.

Figure 4.7 – Total Number of Housing Units per Census Block

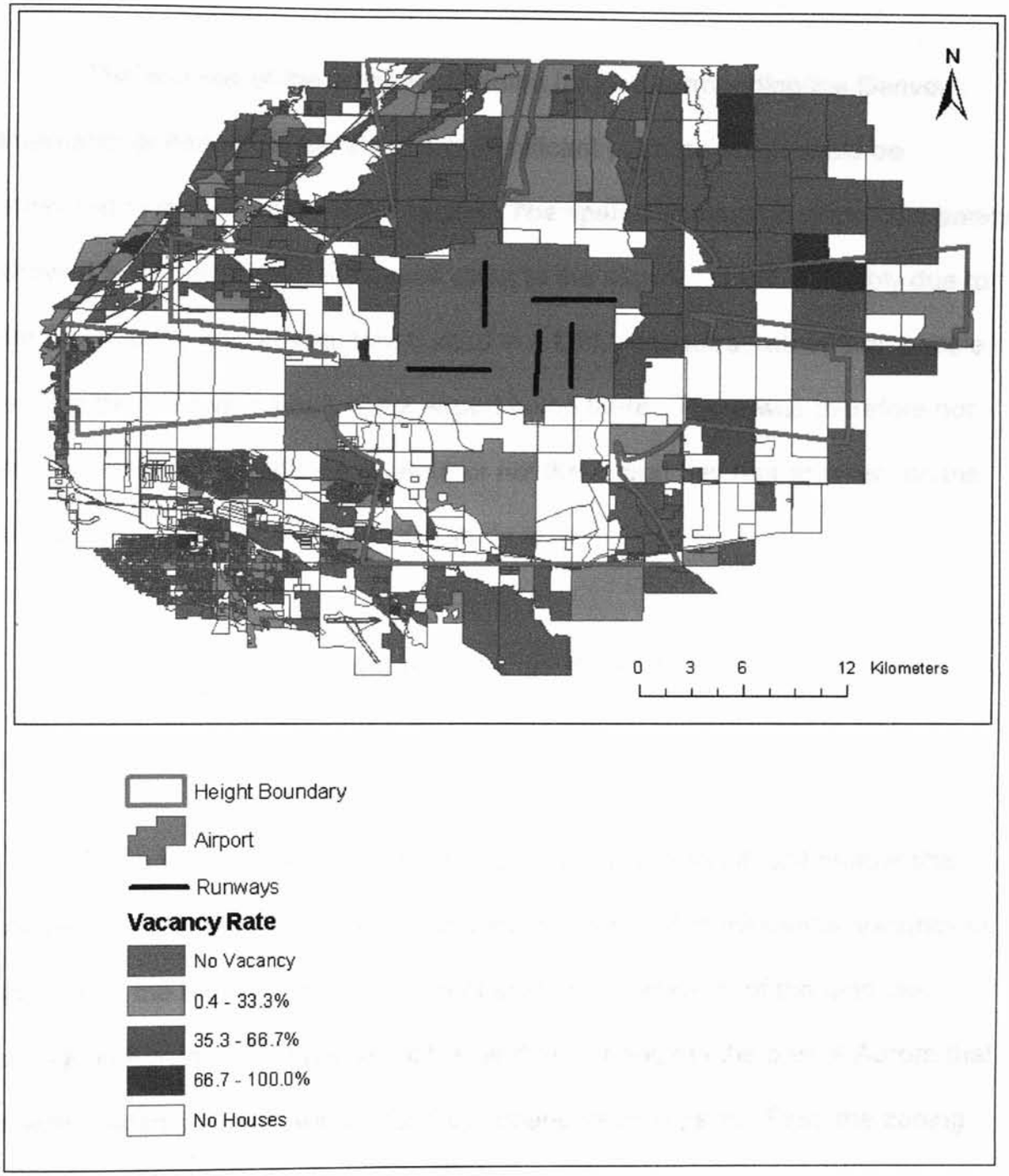


The Rocky Mountain Wildlife Refuge, located just north of the more urbanized southwest part of the study area, stands as a physical barrier to the encroachment of the metropolitan area in that direction. This large area of non developed land is not without benefit to the surrounding community, since the western height boundary is almost entirely contained within this area (Figure 4.7). The presence of the Wildlife Refuge will therefore limit the amount of development that might be negatively affected by the operation at the airport.

Figure 4.7 further shows a larger number of blocks with no houses in the immediate vicinity of the airport. This should probably been seen more as a result of the airport having been constructed in a rural area with a limited number of houses rather than as a result of the presence of the airport. The problem in a spatial comparison of census blocks is that they are not the same physical size. Therefore, in order to get a better picture of the housing characteristics surrounding the airport, the percent of vacant houses was calculated per block.

It was expected that the percent of vacant housing units would be inversely related to the distance from the airport. Figure 4.8 shows that the percent of vacant houses does not increase as you get closer to the airport, as compared to the area outside the airport height boundary. It could therefore not be conclude that the airport has had a negative impact on the vacancy rate within the study area since there is a large number of blocks within the immediate vicinity of the airport that have no vacancy.

Figure 4.8 – Vacancy Rate per Census Block



Summary

The analysis of the amount of vacant houses surrounding the Denver International Airport did not show any significant patterns which could be attributed to the presence of the airport. The spatial distribution of the occupancy showed a limited number of houses close to the airport. This is probably due to the fact that the airport was constructed in a fairly rural area, rather than people leaving the area as a result of the airport being there. There was therefore not enough evidence to indicate whether or not the airport has had an effect on the amount of vacant houses within the study area.

Land Use Change in Aurora

Analysis

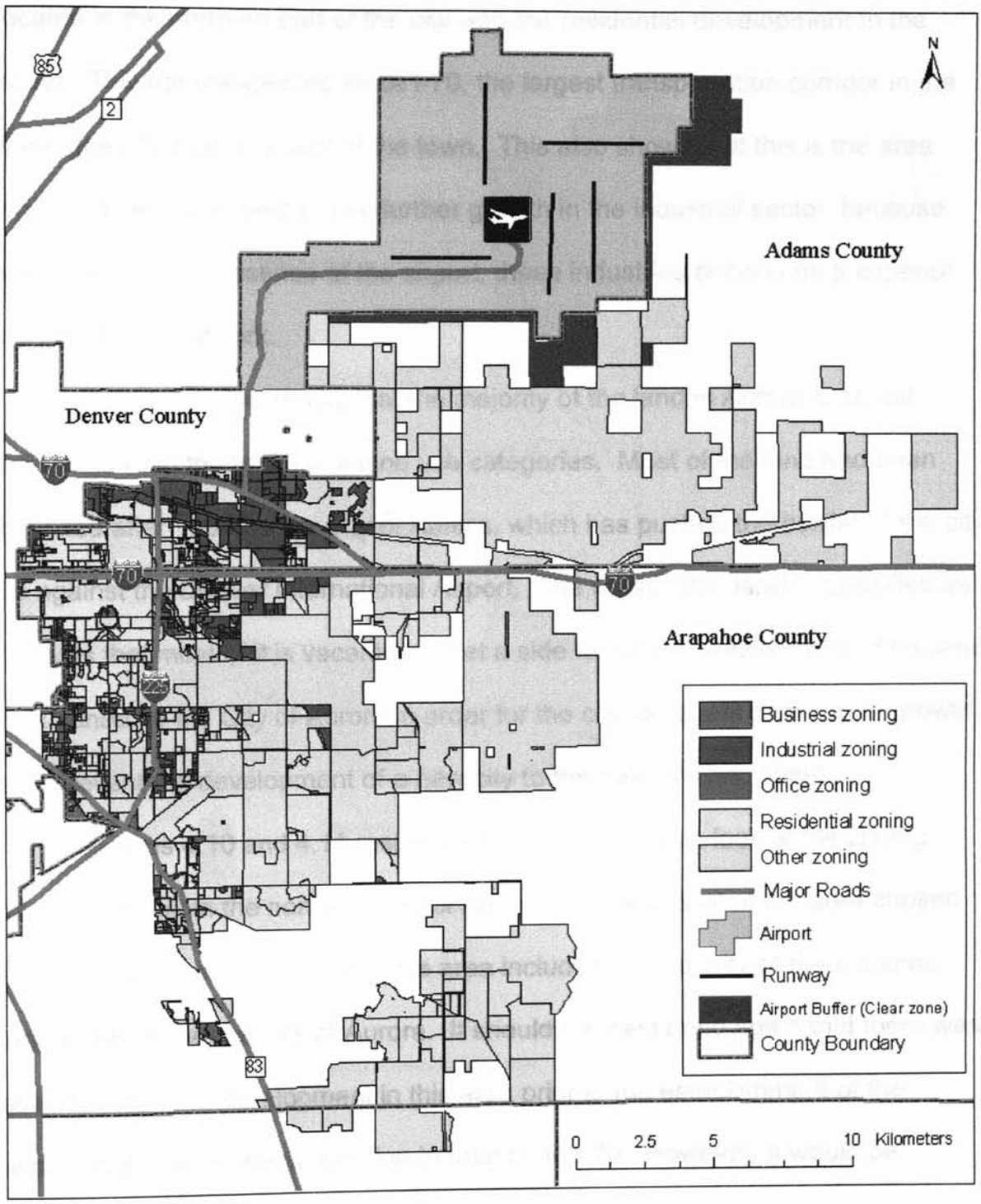
The previous analysis in this study did not find a significant relationship between the increase in the population and the percent of residential vacancy in addition to the airport. The final area of study is an analysis of the land use change in Aurora. The analysis of the land use change in the part of Aurora that is within Adams County will be build up around several parts. First, the zoning patterns within the study area will be compared to the zoning pattern within the entire City of Aurora. Second, the establishment of new parcels in the 1990s will be compared to the establishment of new parcels in the 1980s in order to determine which type of development grew significantly more in the 1990s as

opposed to the 1980s. Third, a two-sample difference of proportions test will be utilized to determine if there has been a significant growth of the land use categories compatible with the operations at the airport. The data used in this study included the parcel information for the northern part of Aurora, the zoning boundaries for the City of Aurora, and the entire Adams County. The City of Aurora uses 101 different parcel categories to define their parcel information; of these it was determined that twenty could be related to the operations at the airport.

Results

The establishment of a comprehensive land use and zoning plan are of great importance to cities and local governments concerning airports, because they aid in the control of desired and undesired land use. This was also the case in Aurora, where the city developed a comprehensive land use plan in order to control future growth (Weiss, 1989). Figure 4.9 shows the zoning boundaries within the entire City of Aurora. The first thing that stands out when looking at the airport and the zoning boundaries is the airport buffer zone south and east of the airport, in which land has been set aside by the Adams County Planning Department as a buffer between the airport and the surrounding community. This area will limit the amount of development, especially underneath the take-off and approach corridor, which is the area most susceptible to the exposure of noise.

Figure 4.9 – Zoning Boundaries Within the City of Aurora



Another noticeable pattern is that the majority of the industrial zoning is located in the northern part of the city with the residential development to the south. This not unexpected since I-70, the largest transportation corridor in the area, goes through this part of the town. This also shows that this is the area where you would expect to see further growth in the industrial sector, because even without the presence of the airport, these industries depend on a superior transportation network.

Figure 4.9 also shows that the majority of the land in Aurora is zoned differently than the traditional land use categories. Most of the land had been annexed after 1989 by the City of Aurora, which has pushed the border of the city up against the Denver International Airport. The reason this land is classified as Other is that most of it is vacant land set a side for future development. This land was zoned by the City of Aurora in order for the city to benefit from future growth and prevent the development of a new city to the east (Weiss, 1989).

Figures 4.10 and 4.11 respectively show a close up look at the zoning boundaries within the northern part of Aurora and the extent of the area chosen for the analysis of the parcels. This area includes the majority of the industrial land within the entire City of Aurora. It should be mentioned again that there was already industrial development in this area prior to the establishment of the airport due to its strategic location in relation to I-70. However, it would be expected that part of the new development can be credited to the presence of the airport, since it is the single largest change in the area since 1990. There is also a large part of the area in the northern part of Aurora that is zoned Other, of

Figure 4.10 – Zoning Boundaries for the City of Aurora Within Adams County

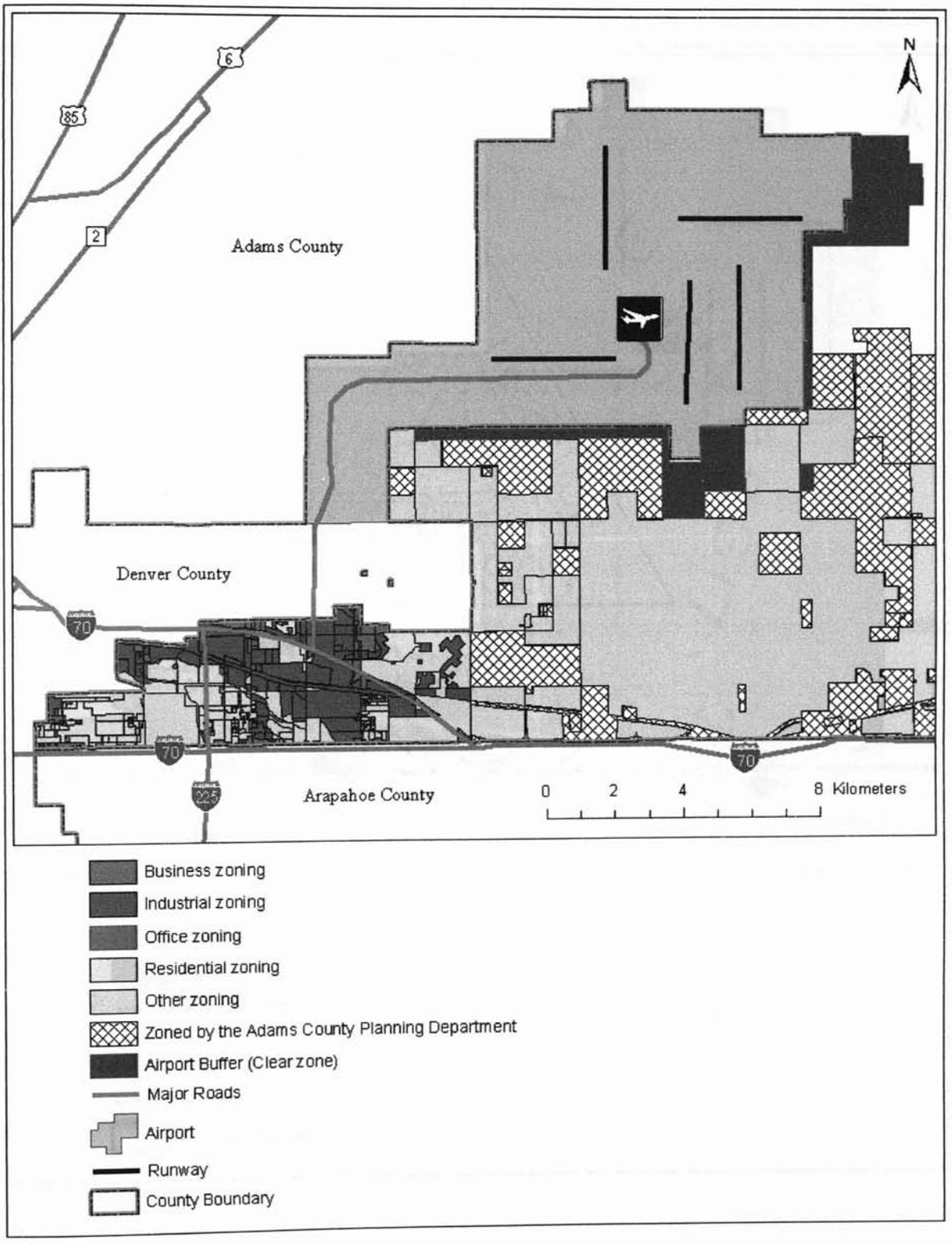
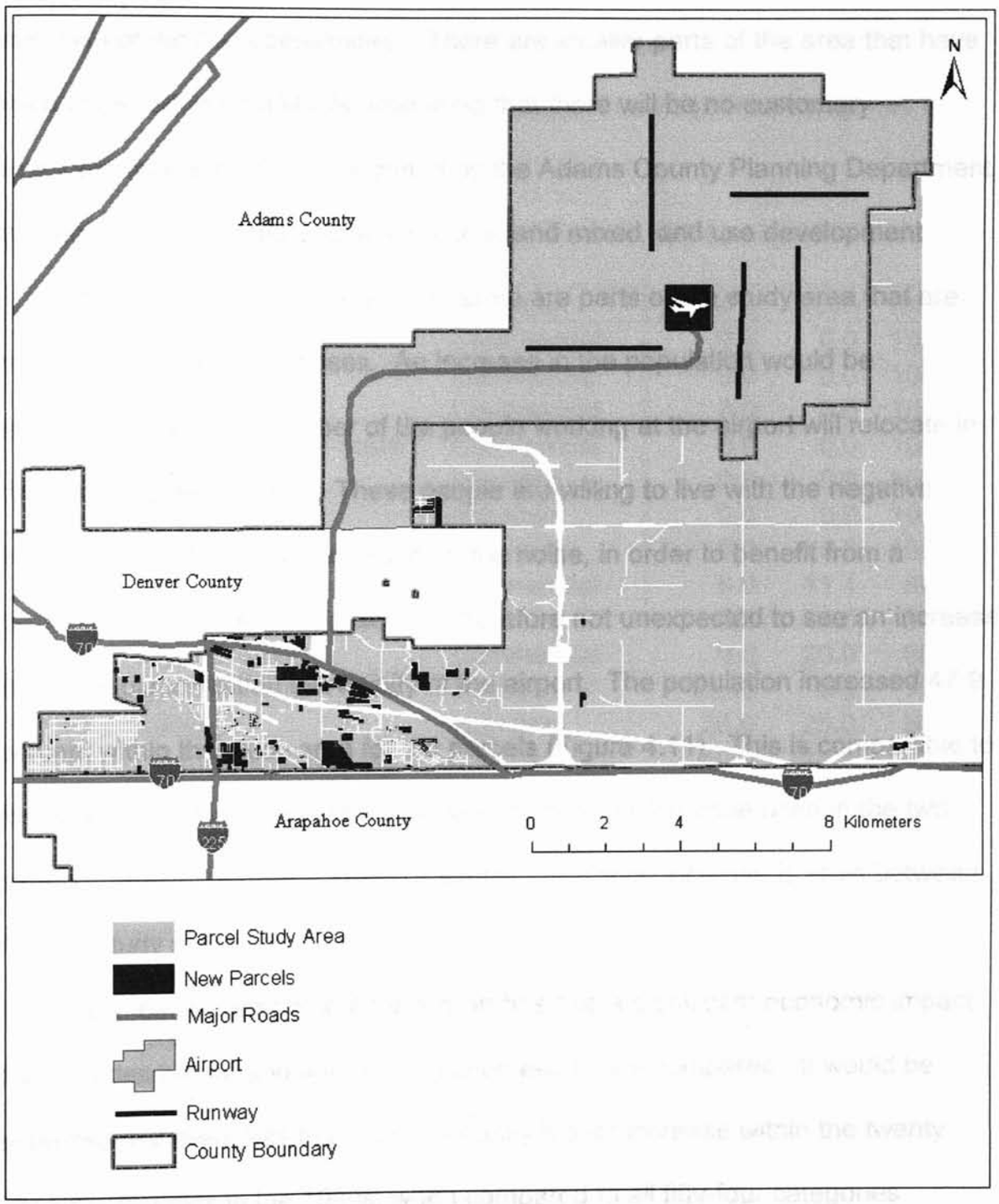


Figure 4.11 – The Study Area for the Parcel Analysis Including All Parcels Built After 1990



which almost all of this set aside for further development. This includes a corridor for the E-470 toll road, mixed land use development, and parts where the use has not yet been determined. There are smaller parts of the area that have been zoned as open districts, indicating that there will be no customary development there. The area zoned by the Adams County Planning Department is mainly zoned as agricultural, industrial, and mixed land use development

Figure 4.10 further shows that there are parts of the study area that are zoned for residential purposes. An increase in the population would be expected, because a number of the people working at the airport will relocate in order to be closer to work. These people are willing to live with the negative impact created by the airport, such as the noise, in order to benefit from a decrease in transportation cost. It is therefore not unexpected to see an increase in the population within the vicinity of the airport. The population increased 47.9 percent within the study area for the parcels (Figure 4.11). This is comparable to the 48.9 percent increase within the ten-kilometer buffer zone used in the two previous studies (Figure 3.2). So a similar population increase is seen between the two study areas.

In order to determine if the airport has had a significant economic impact, the decades before and after construction began are compared. It would be expected that there has been a significantly higher increase within the twenty impact categories in the 1990s, when compared to all fifty-four categories (Appendix B). If the airport did have an impact, it would be expected that the percent of the total within the twenty impact categories would be higher in the

1990s because of the extra business generated by the airport. Table 4.4 shows the twenty-seven categories that did experience an increase during the 1990s. It can be seen that eighteen of the twenty impact categories did experience positive growth during the 1990s. Only three of these eighteen categories had

Table 4.4 – Percent of Total Number of Parcels, Ranked by 1990 Values

Built As	Land-use	Pre-1979	1980s	1990s
Car Wash – Automatic	Commercial	0.0	0.0	100.0
Health Club	Commercial	0.0	0.0	100.0
Modular Office *	Commercial	0.0	0.0	100.0
Warehouse Showroom Store *	Commercial	0.0	0.0	100.0
Hotel - Full Service *	Industrial	0.0	0.0	100.0
Retail Store	Industrial	0.0	0.0	100.0
Warehouse Showroom Store *	Industrial	0.0	0.0	100.0
Parking Lot *	Commercial	0.0	11.1	88.9
Storage Warehouse *	Industrial	6.3	12.5	81.3
Hotel - Full Service *	Commercial	0.0	20.0	80.0
Distribution Warehouse *	Industrial	25.0	0.0	75.0
Office Building *	Industrial	25.0	25.0	50.0
Industry Light Manufacturing *	Commercial	40.0	20.0	40.0
Convenience Store	Commercial	54.5	9.1	36.4
Bank	Commercial	33.3	33.3	33.3
Transit Warehouse *	Commercial	33.3	33.3	33.3
Industry Light Manufacturing *	Industrial	33.3	33.3	33.3
Storage Warehouse *	Commercial	26.7	50.0	23.3
Mini Warehouse *	Commercial	55.6	22.2	22.2
Office Building *	Commercial	66.7	14.0	19.3
All categories (14) **	Exempt	79.2	8.3	12.5
Fast Food Restaurant *	Commercial	44.4	44.4	11.1
All categories (31) **	Residential	73.4	17.8	8.8
Restaurant *	Commercial	87.5	6.3	6.3
Distribution Warehouse *	Commercial	59.6	36.7	3.6
Retail Store	Commercial	85.1	12.2	2.7
Service Garage	Commercial	69.4	29.0	1.6

* Built as category identified as airport related land-use

** Number in parentheses identifies the number of built as categories

less growth during the 1990s when compared to the previous decade. Of the remaining fifteen, eleven had a larger percent growth during the 1990s, and four experienced the same growth.

Table 4.4 only includes the top half of all the categories compared, because all the categories in the bottom half did not experience any growth in the 1990s. In this analysis 51 of the 54 categories used belonged either to the commercial or industrial land use categories. There are twenty categories identified as possible impact categories, which indicates that thirty-one of the commercial and industrial categories are not related to the airport. Of these thirty-one categories, twenty-four of them did not see an increase during the 1990s. There is therefore enough evidence to conclude that the twenty impact categories related to the presence of the airport have seen a significantly higher growth than those not influenced by the presence of the airport. The northern part of Aurora has seen a significant development in land use activities such as warehouses, office buildings, and light manufacturing when compared to barber shops, laundromats, and day care centers.

A very similar result is seen if the data is ranked by the total number of new parcels in the 1990s (Table 4.5). This table further reveals that the categories there have seen a significant number of new development in storage warehouses, office buildings, parking lots, distribution warehouses, and hotels. These are again categories possibly related to the presence of the airport. In relation, of the first eighteen categories in Table 4.5, sixteen of them are part of the twenty impact categories. It is even more evident here that the categories

Figure 4.5 - Total Number of Parcels, Ranked by 1990 Values

Built As	Land-use	Pre-1979	1980s	1990s
All categories (31) *	Residential	5592	1360	668
Storage Warehouse **	Commercial	23	43	20
Storage Warehouse **	Industrial	1	2	13
Office Building **	Commercial	38	8	11
Distribution Warehouse **	Industrial	3	0	9
Parking Lot **	Commercial	0	1	8
All categories (14)*	Exempt	38	4	6
Distribution Warehouse **	Commercial	99	61	6
Hotel - Full Service **	Commercial	0	1	4
Convenience Store	Commercial	6	1	4
Warehouse Showroom Store **	Commercial	0	0	3
Hotel - Full Service **	Industrial	0	0	2
Warehouse Showroom Store **	Industrial	0	0	2
Office Building **	Industrial	1	1	2
Industry Light Manufacturing **	Commercial	2	1	2
Industry Light Manufacturing **	Industrial	2	2	2
Mini Warehouse **	Commercial	5	2	2
Fast Food Restaurant **	Commercial	8	8	2
Retail Store	Commercial	63	9	2
Car Wash – Automatic	Commercial	0	0	1
Health Club	Commercial	0	0	1
Modular Office **	Commercial	0	0	1
Retail Store	Industrial	0	0	1
Bank	Commercial	1	1	1
Transit Warehouse **	Commercial	1	1	1
Restaurant **	Commercial	14	1	1
Service Garage	Commercial	43	18	1

* Number identifies the number of built as categories

** Built as category identified as airport related land-use

that have seen the most significant increase are the ones related to the airport.

A similar approach is used to compare the change within the fifty-four categories used above, but instead using the number of square feet. This analysis will not be included here because it produced almost an identical result to the one found using the number of parcels.

The previous analysis shows that there has been an increase in the land use categories linked to the presence of the airport. It is recognized however that not all the growth within these categories is caused by the airport. Taking this into consideration, the next step is then to determine the overall change and possible impact of the airport. This is done by summarizing the total number of square feet within the twenty impact categories into more general categories, such as not distinguishing commercial from industrial (Table 4.6). The data are reported by the total number of square feet that has been constructed during the 1990s within these more generalized categories. The table shows that there was less warehouse space created in the 1990s as opposed to the 1980s, but more

Table 4.6 – Total Number of Square Feet

Built As	Pre-1979	1980s	1990s
Distribution Warehouse	8,512,035	1,666,219	302,628
Mini Warehouse	176,478	93,639	150,850
Storage Warehouse	502,781	3,904,033	3,185,204
Transit Warehouse	16,400	40,620	13,000
Warehouse Showroom Store	0	0	418,421
Total Warehouse Space	9,207,694	5,704,511	4,070,103
Office Building	219,255	212,379	560,226
Modular Office	0	0	560
Total Office Space	219,255	212,379	560,786
Fast Food Restaurant	9,746	26,142	6,880
Restaurant	41,030	2,568	4,755
Total Restaurants Space	50,776	28,710	11,635
Parking Lot	0	370,359	1,654,636
Hotel - Full Service	0	170,145	446,640
Industrial Engineering & Research	102,506	0	0
Industry Light Manufacturing	92,114	188,864	265,355
Motel	86,101	0	0

than 4 million square feet is still a noticeable increase. There was a lot of warehouse space in the area prior to the establishment of the airport, which is most likely due to the presence of I-70. Also, there is the fact that a large part of this area is located within the proximity of the former site of Stapleton International Airport, the old airport. This also means that some of the companies in the area did not have to relocate in order to take advantage of the new airport. The area did see a larger amount of development in the 1990s within the hotels, parking lots, and office space categories. In addition, the area has experienced a continued increase in the amount of light manufacturing. The development of business space set aside for restaurant business decreased by more than half. Even though not all the impact categories saw the same level of development in the 1990s as opposed to the 1980s, it can still be concluded that there has been a significant addition of business space in the area. This means that the City of Aurora has been able to expand its employment base during the 1990s, which would be a positive economic spinoff from the relocation of the airport. Another benefit is that of an increased tax base. It was expected that the airport would generate the demand for several million square feet of new business space (Weiss, 1989). More than five million square feet of business space has been developed since 1990, so the area has seen a significant amount of development since the airport was planned.

The next step is to test the significance of the difference between the different land use categories: residential, commercial, industrial, and exempt. The question is: Does the proportion of one land use type differ from that of

another? For example, is the proportion of industrial land use significantly different from that of residential, commercial and exempt land uses? A series of two-sample difference of proportions tests is run (Equation 3.8), a separate test for each possible pair of the four categories. Tables 4.7 and 4.8 respectively show the proportions used in these tests and the test results using these proportions.

Table 4.7 – Data Used in Difference of Proportions Test: Total Number of Parcels per Land-Use Category

Land-use		After 1990		Before 1990	
	Total	Number	Proportion	Number	Proportion
Commercial	593	71	0.12	522	0.88
Agricultural	13	0	0.00	13	1.00
Exempt	48	6	0.13	42	0.88
Industrial	44	31	0.70	13	0.30
Residential	7620	668	0.09	6952	0.91

Table 4.8 – Difference of Proportions Test Results: Number of New Parcels

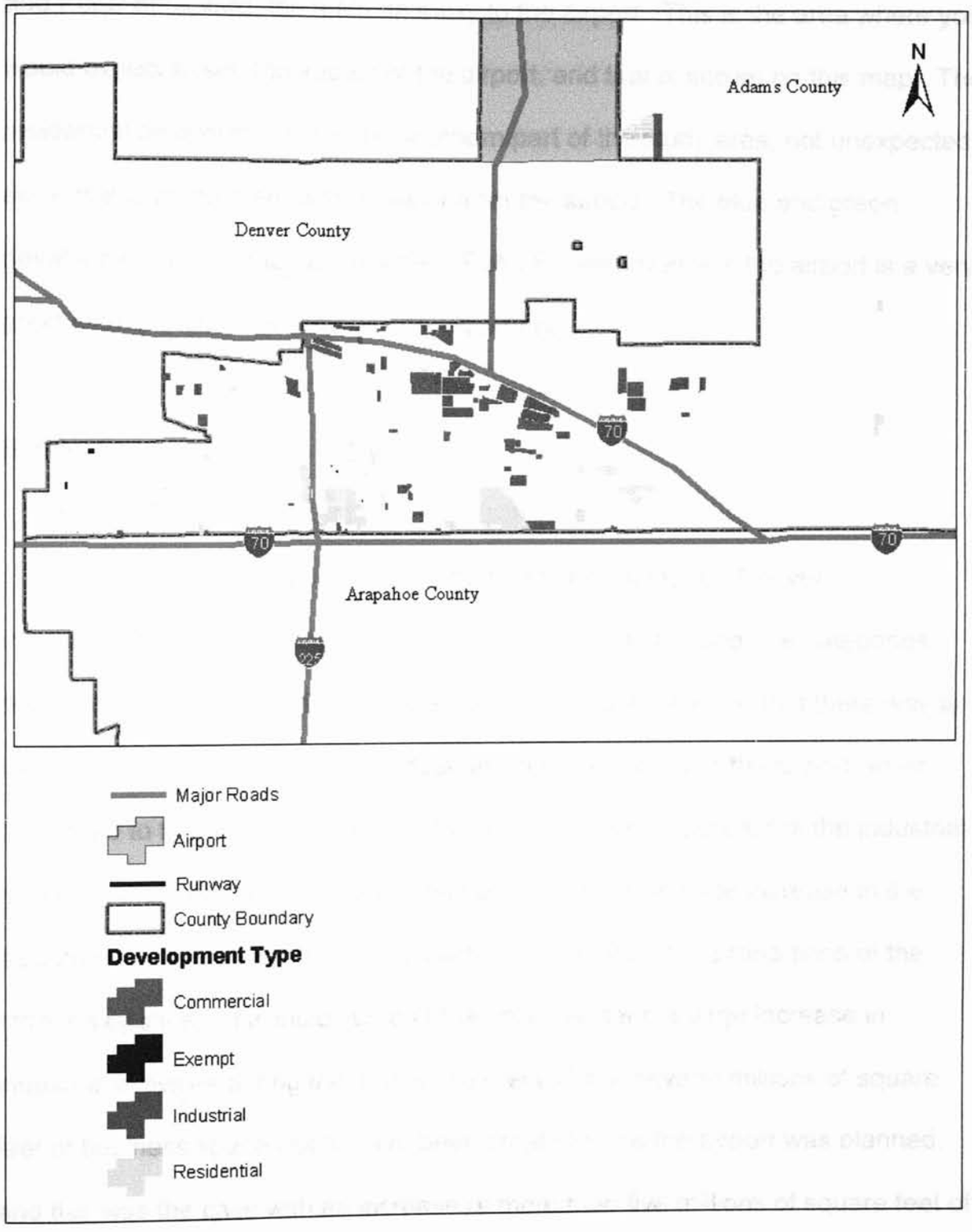
Land-use	Commercial	Exempt	Residential
Industrial	Z = 10.12 p = 0.0000	Z = 5.57 p = 0.0000	Z = 13.86 p = 0.0000
Commercial		Z = 0.20 p = 0.4190	Z = 2.43 p = 0.0075
Exempt			Z = 0.96 p = 0.1675

The largest difference of proportions in Table 4.8 occurs when industrial is contrasted with residential. Not surprisingly, the proportion of new parcels is .70 for the industrial, as opposed to .09 for the residential. The associated p-value of zero very strongly suggests that these proportions are indicative of a true difference in the number of new parcels within these two land use categories. Similarly, a strong difference exists between the industrial category and the commercial and residential land use categories. In addition, a fairly strong difference exists between the commercial and residential category. The two-sample difference of proportions test shows that there has been a significant growth in the industrial category when compared the other three variables. There has also been an increase in the amount of commercial activity when compared to residential. Agriculture was not compared to any of the other four categories since there had not been an increase in any land use types classified as agriculture.

This test shows that there has been a positive development in the industrial and commercial land use categories. In relation, the comparison of the 1980s and 1990s above showed that the bulk of the increase within these two categories came from development identified as compatible to the airport. This includes the addition of numerous square feet of warehouse and office space compatible to the presence of the airport.

Figure 4.12 shows the new parcels that have been built since 1990 in the area just south of the airport. This development is closely tied to the zoning boundaries in the area, but it can also be seen that the bulk of the industrial and

Figure 4.12 – New Development by Land-Use Type



commercial development is in the area surrounding the junction between I-70 and Peña Boulevard, the main gateway to the airport. This is the area where you would expect to see the impact of the airport, and that is shown on this map. The residential development is in the southern part of the study area, not unexpected since this is in the area furthest away from the airport. The blue and green development just to the east of where Peña Boulevard enters the airport is a very good example of mixed land use development.

Summary

The analysis of the parcel information surrounding the Denver International Airport did show a significant increase in the land use categories determined to be related to the presence of the airport. I found that there was an increase in the commercial and industrial activities related to the airport, when compared to the ones not related to the airport. Seventy percent of the industrial activity in the area has been developed after 1990. This large increase in the industrial sector proved to be significantly different from the proportions of the other categories. This indicates that the area has seen a large increase in industrial activities during the 1990s. I expected that several millions of square feet of business space would have been created since the airport was planned, and this was the case with an increase of more than five millions of square feet of new business space.

I also found that there had been an increase in the population within the northern part of Aurora. This was not unexpected since people employed at the airport would be expected to move to the area. This not saying that all the people that moved to the area are employed at the airport.

I also found that the airport has had an impact in the area when looking at the zoning boundaries, because of the strip of land there has been set aside as a buffer between the airport and the community of Aurora. This buffer will help prevent development of undesired land use, especially underneath the take-off and approach corridor.

CHAPTER V

CONCLUSION

In conclusion, four sections are addressed in order to determine the impact the Denver International Airport has had on the surrounding community. The first is an evaluation of the research questions and hypothesis through a discussion of the research findings. The second compares the problem statement to the research findings. The third examines the limitations of the study. The final section discusses possible future research efforts.

Evaluation of Research Questions and Hypothesis

This section is an evaluation of the research questions used to evaluate the hypothesis. The majority of this discussion will be focused on the findings in the study of the land use changes in Aurora, due to the more detailed methods used in that study. It can be concluded that there has been a distinct change in the land use surrounding the airport. I found that the proportion of new industrial activities was statistically significant when compared to the other land use categories in the northern part of Aurora. This included an increase in activities such as warehouses, office buildings, hotels, and light manufacturing. Seventy percent of all the industrial activity in the part of Aurora studied has been developed since 1990.

The entire area surrounding the airport has seen an increased in the population of almost fifty percent between 1990 and 2000. This means that the surrounding area has also seen an increase in residential activities in addition to the increase in industrial activities. The majority of the increase in the population, eighty-two percent, came from an increase of the Hispanic population. This stands in contrast to the fifty-six percent the Hispanic population contributed to the overall population growth within Adams, Arapahoe, and Denver County. The Hispanic population therefore grew faster within the 10-kilometer when compared to the entire area of the three Counties.

The area has also seen an increase in commercial activity, especially parking lots, hotels, and office buildings. This occurred through the construction of one and a half million square feet of parking space, four new hotels, and eleven new office buildings.

As already mentioned, there has bean a noticeable increase in the activities there can be logically attributed to the presence of the airport. This includes compatible land use activities such as commercial and industrial. When comparing the commercial and industrial activities logically related to the presence of the airport to those not related to the presence of the airport, there has been a significant increase in the activities related to the airport. The activities that saw the most significant increase were storage warehouses, office buildings, parking lots, and distribution warehouses. It is also believed that part of the increase in the population can be attributed to the presence of the airport, since people want to live close to their point of employment.

It is more difficult to determine from the research findings in this study if the airport has had a positive effect on the areas close to the main entrance and a negative effect in areas further away, especially those affected by the noise produced by the airport. I found that there was a positive effect in the area surrounding the junction I-70 and Peña Boulevard, the access road to the airport. This was the area with the most significant development in the activities related to the presence of the airport. If the noise has had an impact on the area is harder to determine from the findings, because no significant pattern was found when the airport noise and height boundary was compared to the vacancy rate in the area surrounding the airport. The lack of a significant relationship between the airport and the negative effects was due to the fact that the areas affected by the airport are very sparsely populated areas, especially within the noise boundary. Therefore, only a limited amount of negative impact was detected through this research.

As a whole, this research supports the hypothesis that the land use patterns around Denver International Airport have changed statistically from the time the airport was planned in 1989 to the present. A significant change in the land use patterns was found especially within the northern part of Aurora. One issue that had to be considered was if the impact was created by the airport or something else. In regards to this, the study of the parcel information for the City of Aurora proved more useful in the determination of the impact.

Evaluation of Problem Statement

Projections for the expected impact of an airport are often very optimistic and it was therefore of great interest to see if there has actually been a distinct change in the land use and what might explain this. The Organization for Economic Co-operation and development (OECD) was right in its assumption that if an airport is constructed outside the city, as was the case in Denver, it will pull the development of that city in the direction of the airport by attracting compatible land uses. There was an increase in the activities determined to be compatible to the presence of the Denver International Airport. The development has taken place in between the airport and the City of Denver.

This research has found that the activities one would expect to see are the development of various warehouse activities, office buildings, parking lots, and hotels. This not unexpected since this is the type of business that might use the service provided by the airport in their day to day operations. I therefore conclude that part of the increased activity in the area just south of the airport was related to the presence of the airport.

I further conclude that the presence of the airport was also the factor that made a number of people relocate to the area, either because they work at the airport or because they work at the new businesses in the area.

It is also evident that the airport has had an impact when looking at the zoning boundaries. First, the presence of the airport buffer shows that the airport is expected to have an impact on the surrounding community. Second, the

extensive annexations undertaken by the City of Aurora during the time the airport was planned show that Aurora is expecting to see an extensive development of the area in the future, and that they want to be the ones benefitting form this development.

The goal of this research has been to show if there has been a change in the land use from when the decision to build the airport was made in 1989 until present time. This goal was satisfied through the research methods applied in this study.

Limitations

There are a number of limitations related to this study. First is the choice of study area. The size of the buffer used in the analysis of the census block data could have been chosen differently, which in turn could have produced a different result. The reason I chose the 10-kilometer buffer was that this buffer encompassed almost the entire airport height-boundary and all of the airport noise-boundary. It should therefore be kept in mind that another buffer could have been chosen. The same issue was relevant in the analysis of the parcels data and zoning boundaries in Aurora because here again an alteration of the size of the study area could have generate a different result. In relation, a different result might have been found if the part of Denver County to the north of Aurora had been included. The reason I chose the area I did was that the City of

Aurora was predicted to greatly benefit from the presence of the airport.

The variables used in the two studies using census block data are limited by the availability of census data at the time this study was conducted. The entire 2000 census had not been published at the time this research was completed.

In the study of the parcel information, there was no way of determine if a business had expanded during the 1990s as a result of the presence of the airport. Therefore, only the businesses that were constructed during the 1990s were considered. In relation, this study did not look at areas that had been re-zoned because this information was not available.

Another limitation that should be kept in mind is that the Denver International Airport was not the only factor affecting the economy in that area. Therefore, it therefore can not be said that the airport is the only factor that can be credited for the change in the area.

Recommendations and Future Research

There have been a number of studies of airports and the impact they have had on the surrounding area; this includes economic impact studies and studies of the negative effects. There have only been a few geographical studies of the spatial change on the surrounding area associated with the construction of a new airport. To date, the Denver International Airport has not been studied in this

manner. Therefore, this study was important and might generate the interest of others to engage in similar studies.

I hope that this study will inspire others to study the impact other airports has had on the environment in which they exist. It is believed that other studies might be able to put light of some of the shortcomings of this study.

This study could have been improved if more census variables had been available because this would have enabled me to look at numerous of other housing characteristics and income data. It would therefore be of great interest to look at these when they become available.

It would also be interesting to obtain the parcel information from the City of Denver so a study could be conducted over the entire area surrounding Peña Boulevard. This would also give the researcher the possibility of comparing their findings with the results presented in this study.

Finally, a survey should be used to determine the preference of both people and business in order to determine what role the airport played in their decision to move to the area. It would also enable the researcher to determine if a business expanded due to the presence of the airport. Airports are part of today's society. This research, Land Use Change Surrounding the Denver International Airport Between 1990 and 2000, revealed the Denver International Airport's place within this society.

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APPENDIX A: LIST OF THE 101 BUILT AS CATEGORIES DEFINED BY THE ADAMS COUNTY ASSESSORS OFFICE

Built As	Land-use
1½ Story Fin	Residential
2 Story	Residential
Apartment <= 3 Stories	Exempt
Apartment <= 3 Stories	Residential
Apartment > 3 Stories	Residential
Auditorium	Commercial
Bank	Commercial
Barber/Beauty Shop	Commercial
Barn	Agricultural
Barn	Residential
Bi Level	Residential
Car Wash – Automatic	Commercial
Car Wash - Self Service	Commercial
Church	Commercial
Church	Exempt
Clubhouse	Exempt
Clubhouse	Residential
Condo <= 3 Stories	Residential
Condo > 3 Stories	Residential
Convenience Store	Commercial
Day Care Center	Commercial
Detached Garage	Residential
Discount Store	Commercial
Distribution Warehouse	Commercial
Distribution Warehouse	Industrial
Duplex 1 1/2 Story	Residential
Duplex One Story	Exempt
Duplex One Story	Residential
Duplex Split Level	Residential
Duplex Two Story	Residential
Equipment Implement	Agricultural
Equipment Implement	Commercial
Equipment Implement	Residential
Farm Utility Building	Agricultural
Farm Utility Building	Commercial
Farm Utility Building	Residential
Fast Food Restaurant	Commercial
Fraternal Building	Commercial

Built As	Land-use
Fraternal Building	Exempt
Health Club	Commercial
Hotel - Full Service	Commercial
Hotel - Full Service	Industrial
Industry Light Manufacturing	Commercial
Industry Light Manufacturing	Industrial
Industrial Engineering & Research	Industrial
Jail - Correctional Facility	Commercial
Laundromat	Commercial
Market	Commercial
Medical Offices	Commercial
Medical Offices	Exempt
Mini Warehouse	Commercial
Mobile Home Parks *CODE	Residential
Modular Office	Commercial
Mortuary	Commercial
Motel	Commercial
Multiple - Elderly Assisted Li	Exempt
Multiple - Residential	Commercial
Multiple - Residential	Exempt
Multiple - Senior Citizens	Exempt
Neighborhood Shopping Center	Commercial
Nursery/Greenhouse	Commercial
Office Building	Commercial
Office Building	Exempt
Office Building	Industrial
Parking Lot	Commercial
Parking Lot	Residential
Post Office	Commercial
Ranch 1 Story	Agricultural
Ranch 1 Story	Commercial
Ranch 1 Story	Exempt
Ranch 1 Story	Residential
Restaurant	Commercial
Retail Store	Commercial
Retail Store	Industrial
Retail Store	Residential
School - Classroom	Exempt
School - Elementary/Secondary	Exempt
Service Garage	Commercial
Service Station	Commercial

Built As	Land-use
Shed - Cattle	Residential
Shed - Equipment	Commercial
Shed - Equipment	Residential
Shed - Poultry	Agricultural
Split Level	Residential
Storage Garage	Agricultural
Storage Garage	Commercial
Storage Garage	Residential
Storage Hanger	Commercial
Storage Warehouse	Commercial
Storage Warehouse	Industrial
Townhouse One Story	Residential
Townhouse Two Story	Residential
Transit Warehouse	Commercial
Triplex 1 1/2 Story	Residential
Triplex One Story	Exempt
Triplex One Story	Residential
Triplex Split Level	Residential
Triplex Two Story	Residential
Veterinary Hospital	Commercial
Warehouse Showroom Store	Commercial
Warehouse Showroom Store	Industrial

Source: Adams County Assessors Office

APPENDIX B: LIST OF 54 CATEGORIES USED IN IMPACT STUDY

Built As	Land-use
All categories (14) *	Exempt
All categories (31) *	Residential
All categories (7) *	Agricultural
Auditorium	Commercial
Bank	Commercial
Barber/Beauty Shop	Commercial
Car Wash - Automatic	Commercial
Car Wash - Self Service	Commercial
Church	Commercial
Convenience Store	Commercial
Day Care Center	Commercial
Discount Store	Commercial
Distribution Warehouse **	Commercial
Distribution Warehouse **	Industrial
Equipment Implement	Commercial
Farm Utility Building	Commercial
Fast Food Restaurant **	Commercial
Fraternal Building	Commercial
Health Club	Commercial
Hotel - Full Service **	Commercial
Hotel - Full Service **	Industrial
Industry Light Manufacturing **	Commercial
Industrial Engineering & Research **	Industrial
Industry Light Manufacturing **	Industrial
Jail - Correctional Facility	Commercial
Laundromat	Commercial
Market	Commercial
Medical Offices	Commercial
Mini Warehouse **	Commercial
Modular Office **	Commercial
Mortuary	Commercial
Motel **	Commercial
Multiple - Residential	Commercial
Neighborhood Shopping Center	Commercial
Nursery/Greenhouse	Commercial
Office Building **	Commercial
Office Building **	Industrial
Parking Lot **	Commercial
Post Office	Commercial

Built As	Land-use
Ranch 1 Story	Commercial
Restaurant **	Commercial
Retail Store	Commercial
Retail Store	Industrial
Service Garage	Commercial
Service Station	Commercial
Shed - Equipment	Commercial
Storage Garage	Commercial
Storage Hanger	Commercial
Storage Warehouse **	Commercial
Storage Warehouse **	Industrial
Transit Warehouse **	Commercial
Veterinary Hospital	Commercial
Warehouse Showroom Store **	Commercial
Warehouse Showroom Store **	Industrial

* Number in parenthesis identifies the number of built as categories

** Built as category identified as airport related land-use

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